Natsurv 14:

Water and wastewater management in the fruit and vegetable processing industry

(Edition 2)

CD Swartz, GO Sigge, PJ Volschenk, CJ van Schalkwyk, B Fundikwa, and C Lourens

WATER RESEARCH COMMISSION

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WATER AND WASTEWATER MANAGEMENT IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY: NATSURV 14 (Edition 2)

FINAL REPORT

to the Water Research Commission

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EXECUTIVE SUMMARY

SCOPE OF THE PROJECT

In the 1980s, the Water Research Commission (WRC) and Department of Water and Sanitation (DWS), as it is now known, embarked on a series of national surveys of the water and wastewater management of several industries in South Africa. These 'NATSURV reports', as they are known, have been well used over the past three decades. However, the South African economy and its industrial sectors have either grown or in some cases shrunk considerably since the 1980s, leading to a changed economic landscape.

New technologies and systems have been adopted by some of the industries, meaning that certain information contained in the national surveys can be considered outdated or obsolete. Furthermore, initiatives like the UN CEO mandate, water stewardship initiatives, water allocation and equity dialogues, and others suggest a growing awareness of water use, water security, and wastewater production. In this context, it is now considered an opportune moment to review the water and wastewater management practices of the different industrial sectors surveyed in the NATSURV reports and make firm recommendations on directions for change. This project is a revision and update of one of the NATSURV reports, namely 'NATSURV 14: Water and Wastewater Management in the Fruit and Vegetable Processing Industry'.

RATIONALE

Fruit and vegetable processing industries produce effluent streams that contain high pollutant loadings with a very negative impact on the environment if not treated effectively and satisfactorily before discharged into public water sources or municipal sewage systems. Ineffective treatment or process operations may also lead to serious odour problems. High organic loadings in the effluent streams from the fruit processing activities present considerable problems for municipalities and the environment. Any improvement in water management and minimisation of pollutant loads in these effluent streams will be invaluable in helping contribute to improved water demand management and pollution control in our water-scarce country.

APPROACH AND METHODOLOGY

A comprehensive literature search and review was undertaken to establish the current size, nature and status of the fruit and vegetable processing industry (FVPI), both locally and internationally. The emphasis was on water and especially wastewater management in the industry. The local industry was mapped and quantified as comprehensively as possible. Included were water usage rates for different types of FVPIs, their specific water intakes and the volumes of effluent generated.

Based on the mapping of all FVPIs on a national basis, a representative sample of all the different types and sizes of industries was selected for further study. These selected FVPIs were visited, surveys undertaken, and assessments made of the various process steps – including the volume of water used in the preparation processes, effluent volumes generated and discharged, recycling practices, and specific water intake practices. Details on specific pollutant loads were also obtained. The survey also gathered information on wastewater treatment processes used in the fruit and vegetable processing industries for the removal of mainly organic material and locations at which effluent was discharged.

The processes used for the treatment of the discharged effluent were critically evaluated from a water economy, effluent generation, and energy consumption perspective, as well as the treatment efficiency of the removal of the most important pollutants from the effluent. Best practices were identified and recommendations provided for best and preferred technologies to be used in the FVPI and for optimising or improving existing treatment processes (this evaluation is in progress and will be completed for inclusion in the final report).

KEY FINDINGS

A key feature of the FVPI at present is its strong export-oriented approach to production and its focus on intra-Africa trade in particular. The pivotal commodities in the industry are fruit juice concentrates and canned vegetable products, with a total production value of slightly over ZAR 10 billion and ZAR 6 billion in 2014, respectively. Another important aspect of the industry is its highly competitive and concentrated nature, with a few key players controlling large portions of both production and employment. The locations of processing facilities are generally determined by their proximity to raw inputs, with only a few exceptions. The Western Cape was found to be the leading location of processing facilities, where the juicing and canning of deciduous fruits dominated. The Eastern Cape, the Northern Cape, Limpopo, and Mpumalanga are other key provinces where fruit and vegetable processing take place.

The average specific water intakes (SWIs) for canning were found to be 6.81 m^3/ton of raw material and 8.22 m^3/ton of product, for juicing it was 3.79 m^3/ton of raw material and 4.45 m^3/ton of product, for freezing it was 16.3 m^3/ton of raw material and 4.8 m^3/ton of product, and for drying it was 1.3 m^3/ton of raw material and 15.0 m^3/ton of product. The average SWIs for all these processing types were 6.71 m^3/ton of raw material and 7.96 m^3/ton of product. The corresponding SWI values that were reported in the first version of the NATSURV for the FVPI (1987) were 8.79 m^3/ton for canning, 1.29 m^3/ton for juicing, 14.5 m^3/ton for freezing, and an average of 9.29 m^3/ton for all the process types (all expressed in terms of tons of raw material). Drying processes were not reported on in the 1987 version of the FVPI NATSURV.

It is encouraging that some of the facilities reported SWI figures comparable to or better than that of their international counterparts. In addition to this, some facilities performed well in relation to the SWIs established for certain products in the original 1987 NATSURV. Many of the facilities have dedicated long-term strategies for improving water use, with one facility in particular having almost halved water consumption over a three-year period. In general, it was found that the cleaning of raw materials and facilities were the main consumers of water, and therefore initial water-saving endeavours should be directed at these operations. It must however be noted that improvements in water efficiency in the South African FVPI are not only motivated by desire for environmental protection or drought-risk mitigation, but also by financial reasons. The costs of water consumption and effluent disposal can be reduced by improving the water efficiency of the processes.

The survey of effluent streams generated in the FVPI found that average volumes of 298 m^3/d from canning processes, 274 m^3/d from juicing processes, 595 m^3/d from freezing processes, and 407 m^3/d for the industry as a whole were discharged. Energy-use figures in the industry were more difficult to obtain, but ranged from around 2 780 kWh/d to 14 000 kWh/d.

Regarding wastewater management, it can be concluded that advanced treatments are not generally practiced within the industry. Whilst most facilities perform at least a primary wastewater treatment, there seems to be less motivation for facilities to invest in secondary treatments – possibly due to the lengthy pay-back periods associated with the capital expenditure. Only three facilities of the 19 included in the final sample practiced advanced/tertiary treatment. The choice of disposal routes for the final effluent was also determined by the nature of the surroundings. Rural settings most commonly saw irrigation as the preferred disposal route, while municipal wastewater systems were most often preferred in urban environments.

RECOMMENDATIONS

A number of factors affecting the FVPI in South Africa need to be addressed to ensure the global competitiveness of the local industry. Some of these include the impact of the COVID-19 pandemic, pricing pressures (local/global), water shortages during periods of drought, economic impacts (access to capital), export regulations, and changing consumer trends.

Regarding water and wastewater management in these industries in particular, the challenges for the producers include reduced water availability (especially during periods of water scarcity) and water quality. Because of the high water quality requirements for water used in food-industry processes, water recycling presents a number of challenges when considered as an option to reduce the freshwater intake of the industry. There is a big need for further research on this and related topics.

Additional topics for future research and projects include those related to the improvement of licensing processes (reducing the ever-increasing delays in obtaining the necessary permissions), the improvement of cooperative governance, an increase in groundwater use in comparison to surface water, the improvement of sensing and flow measurement technologies, and the establishment of effective water-governance partnerships.

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Reference Group	Affiliation
Dr J Zvimba	Water Research Commission (Research Manager)
Dr J Burgess	Water Research Commission (Research Manager)
Ms J Atwood-Palm	South African Fruit & Vegetable Canners' Association (SAFVCA)
Mr R Richards	South African Fruit Juice Association (SAFJA)
Mr H Vlok	Competence Enhancement Solutions (CES)
Ms K Carstensen	Woolworths
Mr F Botha	Dried Fruit Technical Services (DFTS)
Ms Z Maphumulo	Department of Water and Sanitation (DWS)
Ms Z Mboweni	Department of water and Sanitation (DWS)

A word of thanks is also extended to the management and staff of the food and vegetable processing facilities that were visited as part of this project.

CAPACITY BUILDING/COMPETENCE DEVELOPMENT

Capacity building formed a main objective of the project. Two MSc students were given the opportunity to participate in the project, which helped them obtain specialist knowledge about the field of industrial water management and effluent treatment, with an emphasis on the FVPI. These two students will be able to apply their knowledge and skills in future projects working toward reduced water consumption in the FVPI and the minimisation of waste loadings from this industry when effluent is discharged into the environment. The students regarded the optimisation of water and wastewater systems of fruit and vegetable processing facilities to reduce water consumption, effluent generation, and energy consumption (particularly pertaining to water management). In addition, the research was also directed towards improving the quality of highly polluted effluent streams in the FVPI.

The funding of the project by the Water Research Commission is acknowledged gratefully.

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ACRONYMS AND ABBREVIATIONS

COD	Chemical oxygen demand
BOD	Biological oxygen demand
DAF	Dissolved air flotation
FOG	Fat, oil and grease
PO_4-P	Phosphate (as phosphorous)
EC	Electrical conductivity
HVLP	High volume low pressure
MBR	Membrane bioreactor
pH	The measure of acidity or alkalinity of a chemical solution, from 0 to 14
RO	Reverse osmosis
SPL	Specific pollutant load
SS	Suspended solids
SWI	Specific water intake
TDS	Total dissolved solids
TDIS	Total dissolved inorganic solids
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
TS	Total solids
UASB	Upflow anaerobic sludge blanket
UF	Ultrafiltration

GLOSSARY OF TERMS

Acid: Substances with a pH of less than 7.0.

Additives: Natural and man-made substances added to a foodstuff for a specific purpose (such as preservatives and colourants) or found in foodstuffs without having been added intentionally (such as pesticides and lubricants).

Adulteration: Deliberate contamination of foods with materials of low quality.

Aerobic: Requiring oxygen.

Alkaline: Substances with a pH of more than 7.0.

Ambient temperature: Temperature of the immediately surrounding environment. Ambient room temperature ranges from 19 to 23°C.

Anaerobe: Organism, especially a bacterium, that does not require oxygen or free oxygen to live.

Anaerobic: Without requiring oxygen.

Aseptic packaging: System wherein the food product and the container are sterilised separately and the containers are filled and sealed in a sterile environment.

Aseptic: Without contamination by microorganisms, i.e. sterile.

Bacteria: Large group of single-celled microorganisms, which can be both harmful and helpful to food.

Blast chiller: Refrigeration unit that rapidly cools foods down from 60° C to 3°C in 90 to 120 minutes or less.

°Brix: Measure of the density of a solution, expressed in degrees Brix (°Brix). The °Brix of a solution equals the percentage of sucrose of the solution at room temperature.

Brix hydrometer scale: Sugar content of a solution at a given temperature. Named for AFW Brix, a nineteenth-century German inventor. The Brix (sugar content) is determined by a HYDROMETER, which indicates a liquid's SPECIFIC GRAVITY (the density of a liquid in relation to that of pure water). Each °Brix is equivalent to 1 g of sugar per 100 g of liquid. Also known as the Plato scale.

Bulk: Method of transporting food in large quantities, requiring portioning at the receiving kitchen. Bulk food may be transported either hot or cold.

Chlorination: Addition of chlorine to water to destroy microorganisms.

Citric acid: Form of acid that can be added to canned foods with the aim of increasing the acidity of low-acid foods as a potential flavour enhancer.

Coliforms: Bacteria (primarily E. coli and Enterobacter aerogenes) used as an indicator of the sanitary quality of food. High levels of coliforms indicate the presence of fecal contamination in food and water.

Conductivity (electrical): Physical property of a food material that determines its ability to conduct electricity and is expressed in Siemens per cm (S/cm). In ohmic heating, it enables heating to occur.

Contamination: Process by which harmful or unpleasant substances (such as metal or plastic material, strong odours, bacteria, or poisons) get into or onto food.

Degradability: Ability of materials to be broken down.

Diluent: Material into which the sample is diluted.

Disinfect: Sanitise something so as to destroy disease-carrying microorganisms and prevent infection.

Disinfectant: Chemical that destroys or inhibits the growth of microorganisms that cause disease.

Effluent: Liquid industrial waste.

Firming agents: Used to make or retain firmness or crispness in fruit and vegetables and to strengthen gels.

Foaming: Development and persistence of bubbles on the surface of fats during frying operations. Persistent foaming and accumulation of thick layers of foam may be indicative of fat breakdown.

Foaming agents: Used to provide a uniform dispersion of gas in a food.

Food preservatives: Prevent spoilage either by slowing the growth of organisms that live on food or by protecting the food from oxygenation. Antimicrobials are preservatives that protect food by slowing the growth of bacteria, moulds and yeasts. Antioxidants are preservatives that protect food by preventing food molecules from combining with oxygen (air).

Food processing: Using food as a raw material and changing it in some way to make a food product.

Food safety: Protecting the food supply from microbial, chemical (i.e. rancidity and browning) and physical (i.e. drying out and infestation) hazards or contamination that may occur during all stages of food production and handling – namely growing, harvesting, processing, transporting, preparing, distributing, and storing. The goal of food-safety monitoring is to keep food wholesome.

Heat processing: Treatment of jars with sufficient heat to enable storing food at normal home temperatures.

Pathogen: Disease-causing agent (usually a living microorganism).

Pesticides: Chemicals used to kill pests.

Pickling: Practice of adding enough vinegar or lemon juice to a low-acid food to lower its pH to 4.6 or below. Properly pickled foods may be safely heat processed in boiling water.

Preserve: Maintain quality and safety of food by removing moisture and/or air.

Preservation index: Number calculated to show that the amounts of acid, sugar, and salt used in pickles will be enough to prevent spoilage.

Preservation: Process used to slow or stop the progression of spoilage. It allows for easier distribution and transport, and the food can be stored for longer before use. Preserving food can be done with heat treatment, sugar, salt, acid, or preservatives.

Preservatives: Additives prolonging the shelf life, such as benzoic and sorbic acid and their sodium and potassium salts.

Product process temperature: Temperature at which the process is performed. Initial temperature and process temperature must be monitored at all points of the process if it is an integral condition for microbial inactivation.

Quality assurance: All the planned and systematic activities implemented within the quality system that control each stage of food production – from raw material harvest to final consumption – and demonstrated as needed, to provide adequate confidence that an entity will meet quality criteria.

Quality control: Series of checks and control measures that ensure that a uniform quality food is produced.

Quality standard: Commonly agreed-upon yardsticks for measuring differences in product quality.

Receiving area: Space provided for the unloading of food and non-food products from commercial trucks and for checking orders for quantity, quality, and completeness.

Recycled: Reused.

Risk analysis: Process consisting of three components: risk assessment, risk management, and risk communication.

Spoilage: Significant food deterioration, usually caused by bacteria and enzymes, which produces a noticeable change in the taste, odour, or appearance of the product.

Stabilisers: Substances which allow food compounds that do not mix well to be mixed and stay in a homogeneous state.

Stability: Relative resistance of a product to an undesirable breakdown or change. For fats and oils, stability may refer to resistance to oxidation, hydrolysis, flavour reversion, and formation of odours and flavours.

Standard operating procedure (SOP): A written procedure that will be followed when operating a food service system.

Sterilisation: Process through which foods are treated to kill all forms of microorganisms and spores. Foods can be sterilised by means of high temperature treatment or with ionising radiation.

Storage area: Area where consumable food (dry, frozen, and refrigerated) and non-consumable products are stored in case lots, bulk packages, and broken case lots on shelving pallets or dunnage racks.

Sulphites: Used to preserve the colour of foods such as dried fruits and vegetables and to inhibit the growth of microorganisms in fermented foods such as wine. Sulphites are safe for most people. A small segment of the population, however, has been found to develop shortness of breath or fatal shock shortly after exposure to these preservatives. Sulphites can provoke severe asthma attacks in sulphite-sensitive asthmatics.

Thickeners: Used to increase viscosity, modify texture, and impart stability.

Adapted from *'Definitions of words used in Food Processing: Extensive glossary of food manufacturing, science and technology.* (2013) Arrow Scientific.

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 CONTEXTUALISATION

In the 1980s, the Water Research Commission (WRC) and Department of Water and Sanitation (DWS), as it is now known, embarked on a series of national surveys of the water and wastewater management of several industries in South Africa. These 'NATSURV reports', as they are known, have been well used over the past three decades. However, the South African economy and its industrial sectors have either grown or in some cases shrunk considerably since the 1980s, leading to a changed economic landscape.

New technologies and systems have been adopted by some of the industries, meaning that certain information contained in the national surveys can be considered outdated or obsolete. Furthermore, initiatives like the UN CEO mandate, water stewardship initiatives, water allocation and equity dialogues, and others suggest a growing awareness of water use, water security, and wastewater production. In this context, it is now considered an opportune moment to review the water and wastewater management practices of the different industrial sectors surveyed in the NATSURV reports and make firm recommendations on directions for change. This project is a revision and update of one of the NATSURV reports, namely 'NATSURV 14: Water and Wastewater Management in the Fruit and Vegetable Processing Industry'.

Fruit and vegetable processing industries produce effluent streams that contain high pollutant loadings with a very negative impact on the environment if not treated effectively and satisfactorily before discharged into public water sources or municipal sewage systems. Ineffective treatment or process operations may also lead to serious odour problems. High organic loadings in the effluent streams from the fruit processing activities present considerable problems for municipalities and the environment. Any improvement in water management and minimisation of pollutant loads in these effluent streams will be invaluable in helping contribute to improved water demand management and pollution control in our water-scarce country.

This NATSURV 14 document, which is the final output of the project, will not only serve as a valuable tool for the various fruit and vegetable processing industries (FVPIs) in the country, but will also sensitise the industries to how they can contribute holistically to reducing water usage and especially effluent generation, as well as improve the quality of the effluent streams that are discharged by these industries. Capacity building in the project will result in renewed efforts to undertake initiatives and projects aiming at improved cost-effective effluent treatment processes.

1.2 AIMS

The main objective of this NATSURV 14 document is to stimulate water saving and pollution mitigation by serving as a comprehensive guide and benchmark tool for a number of stakeholders, including local governments, industry actors, academics, researchers, and engineers.

The specific aims of the survey were to:

- Provide a detailed overview of the FVPI in South Africa, including how it has changed since the first edition of NATSURV 14 was published, and what its projected changes are. Representative samples of the respective industries will be used as case studies.
- Critically evaluate and document the 'generic' industrial processes of fruit and vegetable processing in terms of current practices, best practices, and cleaner production processes.
- Determine the water consumption and specific water intake among fruit and vegetable processors (local and global indicators, targets, benchmarks, and diurnal trends) and recommend targets for use, reuse, recycling, and technology adoption.
- Determine wastewater generation, and typical pollutant loads (diurnal trends), as well as best-practice technology adoption.
- Determine local electricity, water, and effluent treatment prices and the by-laws within which these industries function – critically evaluating whether the trends and indicators are aligned to water conservation demand management and environmental protection imperatives.
- Critically evaluate the FVPI (including wastewater) management processes adopted and provide appropriate recommendations.
- Evaluate the industry's adoption of concepts such as cleaner production, water pinch, energy pinch, life-cycle assessments, water footprints, wastewater treatment and reuse, best available technology, and ISO 14 000 – to name a few.
- Provide recommendations on the best practices for this industry.

1.3 SCOPE

- A comprehensive literature search and review was undertaken to establish the current size, nature, and status of the fruit and vegetable processing industry – both locally and internationally.
- The local industry was mapped and quantified as comprehensively as possible. Water usage rates for different types of FVPIs, their specific water intakes, and the volumes of effluent generated were included.
- Representative samples for all the different types and sizes of industries were selected.
- Selected fruit and vegetable processing industries were (and still are) visited, with surveys and assessments performed of the various process steps – including volumes of water used in the preparation processes, effluent volumes generated and discharged, recycling practices, and specific water intake (SWI). The specific pollutant loads (organic and inorganic) will also be obtained.
- Information was gathered on wastewater treatment processes that are used in the fruit and vegetable processing industries for removal of mainly organic material, and locations at which effluent was discharged.

- Current unit prices were determined from a number of municipalities with fruit and vegetable industries in their area of jurisdiction. Effluent discharge quality requirements were also summarised from the by-laws.
- The treatment processes used for treatment of the discharged effluent were critically evaluated from a water economy, effluent generation, and energy consumption perspective – as well as the treatment efficiency for removal of the most important pollutants from the effluent.
- Best practices were identified and recommendations provided for best and preferred technologies to be used in the FVPI.

1.4 LIMITATIONS

There were a few limitations experienced in carrying out and reporting on this study:

- Time and budget constraints prevented the project team from visiting all of the industries across the country. It was attempted to not conduct the visits during the high season of production for the factories. The project team is confident, however, that the industries that were visited are representative of the national fruit and vegetable industry as a whole.
- Some of the industries visited considered certain information requested as confidential and declined to share this information. This included aspects such as water-use figures.
- The response to questionnaires sent out to representatives of the entire sector was relatively poor, although not totally unexpected. The information gathered in this way nevertheless proved to be valuable.

1.5 KNOWLEDGE DISSEMINATION

Two workshops were held with stakeholders and roleplayers in the sector to present the work that had been done by the time the first workshop was held in October 2020. The NATSURV 14 Project Workshop was a webinar that took place on 29 October 2020, while the second workshop formed part of the WISA 2020 Biennial Conference and was held on 10 December 2020 (also online). At the workshops, the draft NATSURV 14 document was presented to sector representatives, discussions were held, and inputs on improvement of the document solicited. The proceedings of the workshops are presented in an appendix to the NATSURV report. Presentations were made by the project leader and the two master’s students from Stellenbosch University, as well as by the Departmental Chair: Food Science of Stellenbosch University, the South African Fruit Juice Association/South African Fruit and Vegetable Canners’ Association, and the National Centre for Cleaner Production (NCPC) of the CSIR.

CHAPTER 2: OVERVIEW OF THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

2.1 BACKGROUND

Water is a vital resource for human development (Mancosu et al., 2015) and is seen as the central element in the food-energy-water nexus (Oberholster and Botha, 2014). Yet the European Union's Integrated Pollution Prevention and Control (IPPC) Directive of 2006 states that water consumption is one of the key factors contributing to the negative environmental impact of the food industry. While most effluents from the food and drink industry are biodegradable, in some sectors substances like salt or brine are used – which have proven resistant to conventional treatment methods (IPPC, 2006). Wastewater derived from food processing, although not highly toxic, can also have a particularly high polluting potential due to the high chemical oxygen demand (COD) of such processes (Cooke, 2008). Wastewater from these industries has been found to contain extremely high levels of both COD and biological oxygen demand (BOD), with levels commonly 10–100 times higher than those for domestic wastewater (IPPC, 2006) The costs of removing this oxygen demand have risen, whether it be because of using an on-site wastewater treatment plant (WWTP) or because of levies when discharging effluent into a public water course (Cooke, 2008).

Within the food industry, fruit, and vegetable processing has its own key environmental issues – namely high water use, the generation of industrial wastewater, problematic solid output, and high energy use for heating and cooling operations (IPPC, 2006). In Australia, the FVPI has also been identified as one of the sub-industries within the food processing industry with the highest annual water use (Australian Department of Agriculture, 2007). With the food industry in general already defined as 'wet' (i.e. water intensive), this statement carries a lot of weight (Australian Department of Agriculture, 2007).

For benchmarking of facilities, it is obviously necessary to have a reliable source for comparison, but unfortunately publications that deal specifically with the metric evaluation of water usage and water savings for different industries seem to have tapered off from around the early 1980s, with relatively few industry reports issued since the turn of the century (CLFP, 2015; Meneses et al., 2017). Although peer-reviewed publications on general water-usage minimisation techniques used across industries seem scarce, a number of industry/governmental publications do cover such topics (for example, CLFP, 2015; IPPC, 2006; Masanet et al., 2008). Publications on 'green processing techniques' (i.e. water- and energy-friendly technologies) are readily available for example, Chemat et al., 2017). However, these publications often deal with methods that are still in the initial stages of technological maturity and therefore have not found their way into common practices at commercial installations (Jermann et al., 2015). Publications such as those by Jermann et al. (2015) and Leonelli and Mason (2010) do, however, shed light on the rate of adoption of these technologies at a global scale.

2.2 DEFINITION OF FRUIT AND VEGETABLE PROCESSING

According to the Harmonized System (HS) used for export classification, 55 product categories presently fall under 'Preparations of vegetables, fruit, nuts or other parts of plants' (UN Trade Statistics, 2010). However, it must be noted that each of these categories could also include a very broad range of products. For example, H20090 describes any mixture of fruit juices that is unfermented and contains no added spirits (Department of Trade and Industry, 2018). Therefore, an obvious question that arises from this seemingly wide array of goods is how to exactly categorise them according to the processes from which they originate. An issue even more central is that a lack of formal definitions will complicate any investigative procedure – both in terms of scope and execution.

Causing further confusion, many governmental statistical bodies have different definitions for different goods, with a case in point being the South African definition excluding dried soup, while the US definition includes it (Bureau for Economic Analysis, 2017; Stats SA, 2018). Furthermore, IBISWorld (2017) also excludes fruit juices from its definition of fruit and vegetable processing. This omission in the South African context would be nonsensical, however, as fruit juices are the most important products both in terms of quantity and value (Stats SA, 2016). Wherever international statistics are quoted in this review, care will be taken to adjust them to represent the South African definition. Where this is not possible and/or practical, the differences will be clearly described.

In order to avoid ambiguity in any subsequent investigative procedure, it is necessary to first provide a formal definition of fruit and vegetable processing. Statistics South Africa (2018) places fruit and vegetable processing under Standard Industrial Classification (SIC) Code 3013, which describes the following activities:

- Manufacturing of food consisting mainly of fruit and vegetables.
- Preserving of fruit and vegetables by freezing.
- Preserving by other means such as dehydration, drying, and immersion in oil or vinegar.
- Processing of potatoes, including potato flour and meal.
- Manufacturing of prepared meals or vegetables.
- Preserving of fruit and vegetables by canning.
- The manufacture of jams, marmalades, and preserves.

It must however be noted that the definition specifically excludes dried soup mixes (Code 3119) and canned fruit and vegetable juices (Code 3121; Stats SA, 2018).

2.3 STRUCTURE AND SIZE OF THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

2.3.1 The global fruit and vegetable processing industry

The demand for processed fruit and vegetables remained relatively consistent in the five years preceding 2017. Consumption levels remained stable and consumer spending increased (IBISWorld, 2017a). Consumers in developing countries, where industrialisation has led to increasing urbanisation, an expanding middle class, and rising incomes, have particularly driven the demand for processed fruit and vegetables, as has a desire for an increasingly healthier diet (IBISWorld, 2017a).

The global revenue from fruit and vegetable processing (excluding juices) totaled approximately US$ 292 billion in 2016 and is expected to grow to US$ 335 billion by 2022 (IBISWorld, 2017a; Statista, 2018). The breakdown of total global revenue per product category (excluding juices) in terms of sales share is shown in Figure 2.1 (IBISWorld, 2017b). The clear leader is frozen fruit and vegetable products, with a sales share of 48%, followed by canned vegetables with a sales share of 30.3% (Figure 2.1). ‘Other’ includes products such as jellies, jams, dried fruits and vegetables, fruit preserves, and other miscellaneous products.

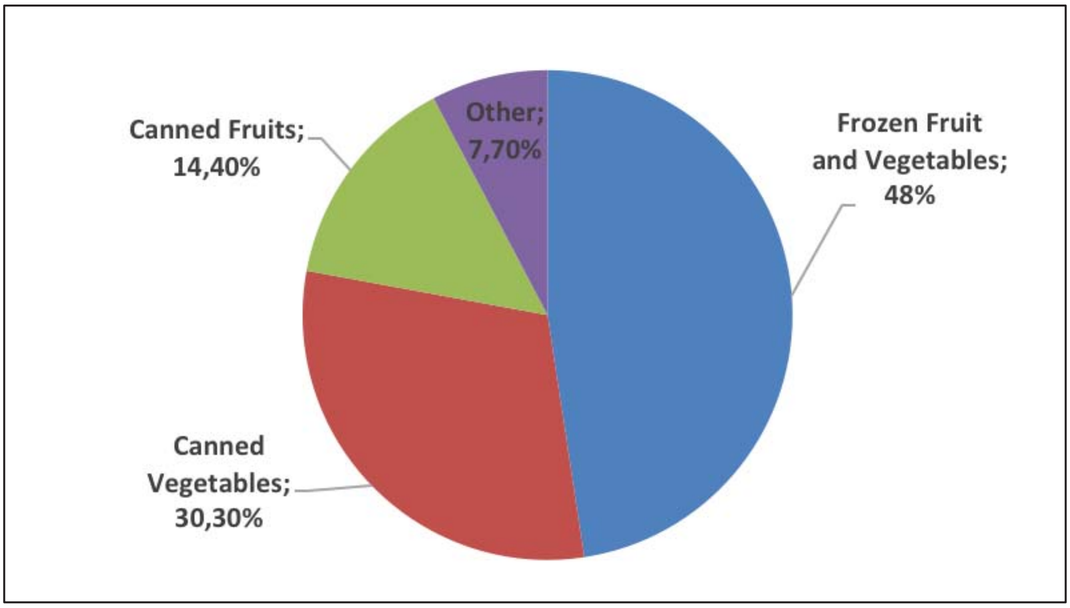

Figure 2.1: Global segmentation of fruit and vegetable processing (excluding fruit juices) in 2017 (IBISWorld, 2017)

North America remains the hub of fruit and vegetable processing, largely due to the increased demand for frozen products in the US and Canada (Bekker, 2018). However, international associations indicate that the key growth areas are expected to be the Asian and South American markets (Bekker, 2018).

2.3.2 The South African fruit and vegetable processing industry

a. Economic contribution and composition

The latest disaggregated data on the South African FVPI was published in 2016, but draws on information collected in earlier years – most notably the 2014 National Census (Bekker, 2018; Stats SA, 2016). According to the 2014 National Census, the manufactured food and beverage industry recorded an income of ZAR 342 billion in that year (Stats SA, 2016), or 19% of the total income for the manufacturing sector (Figure 2.2). The domestic food processing industry is highly concentrated, with a few major players commanding much of the total income and employment of the sector (Bekker, 2018; UNIDO, 2017). South African food processing companies and/or facilities are generally located in urban areas, far removed from the food production areas (Harcourt, 2011), although this may differ for fruit and vegetable processing (Dauthy, 1995) (Harcourt, 2011), where primary processing often occurs closer to the areas of production – especially for fruit processing (Bekker, 2018). This may be due to the high waste levels resulting from primary processing, the limited shelf life of the raw ingredients (Harcourt, 2011), the desire to allow for sufficient ripening before processing, and the reduction of transport-associated damage to raw food products (Dauthy, 1995).

Within the food and beverage industry, the revenue from fruit and vegetable products totalled ZAR 24.07 billion in 2014, or 8% of the total revenue for the South African food-processing industry (Figure 2.3). The leading contributors were alcoholic beverages at 20% and grain products at 18% of the total share, respectively. When looking into the individual components of the FVPI (Figure 2.4), the clear leader in both value and quantity of production is fruit juices. Over 999 000 litres of fruit juice was produced in 2014 with a nominal value of ZAR 10.049 billion. Prepared and preserved vegetable products followed, with slightly over 279 000 tons produced in 2014.

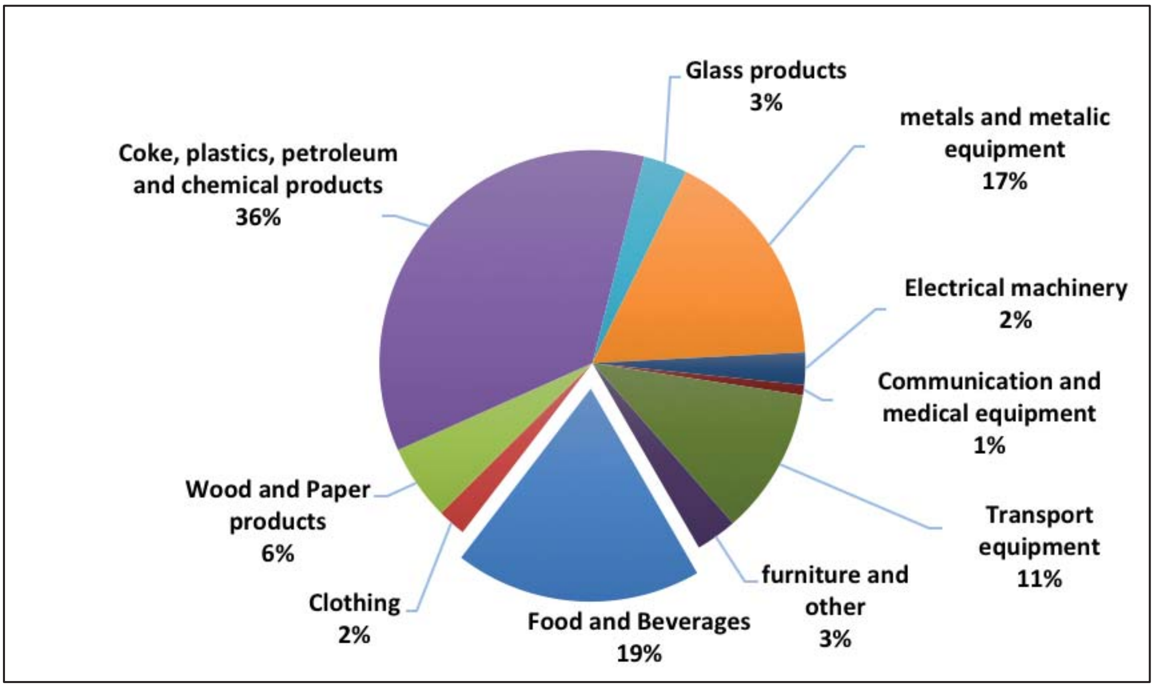

Figure 2.2: Food and beverage share of manufacturing income (StatsSA, 2016)

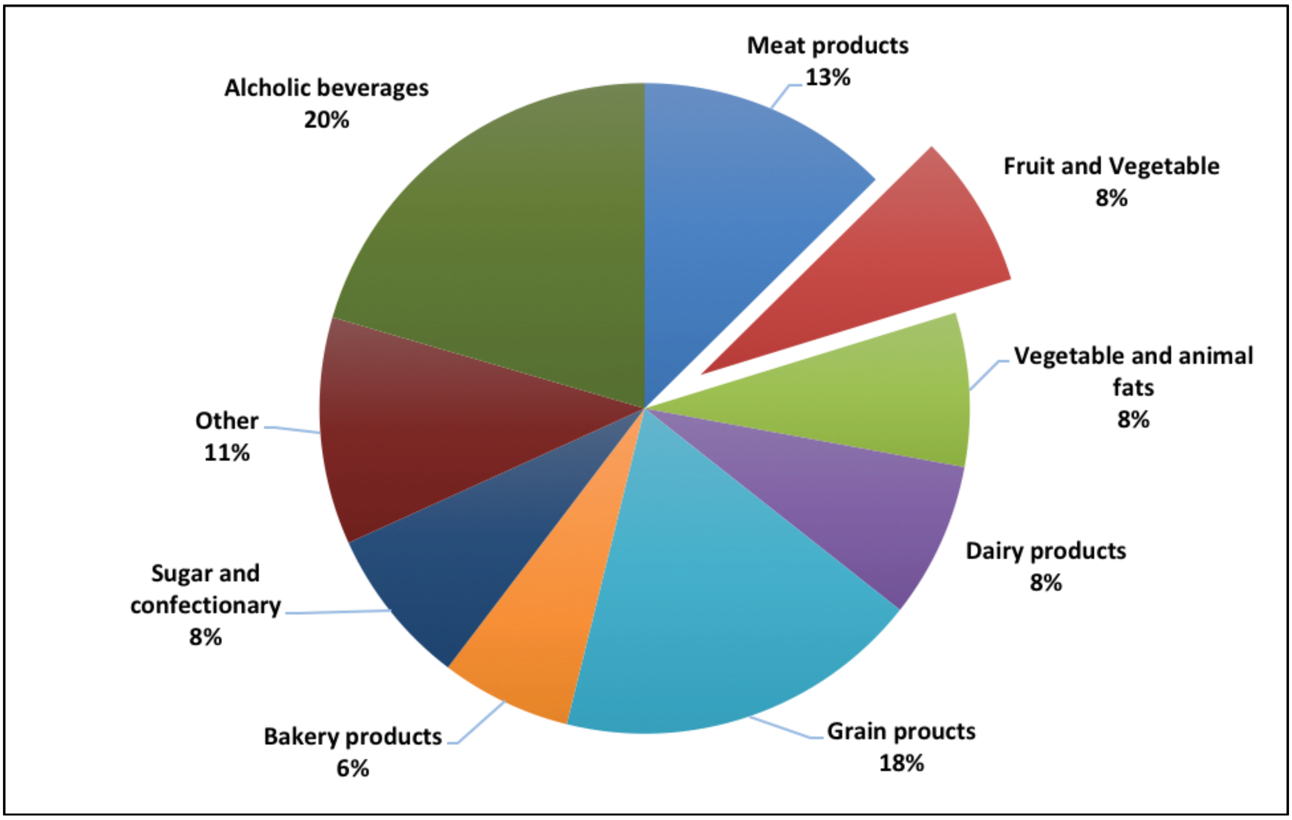

Figure 2.3: Relative contributions of the South African food processing industry (Stats SA, 2016)

Dekker (2018), using the relative contributions for preceding years, estimated that sales of fruit and vegetable preparations (including exports) was between ZAR 21 billion and ZAR 23 billion in 2017, but notes that this is a rough estimate, as the calculations do not consider inflation or relative shifts in production patterns.

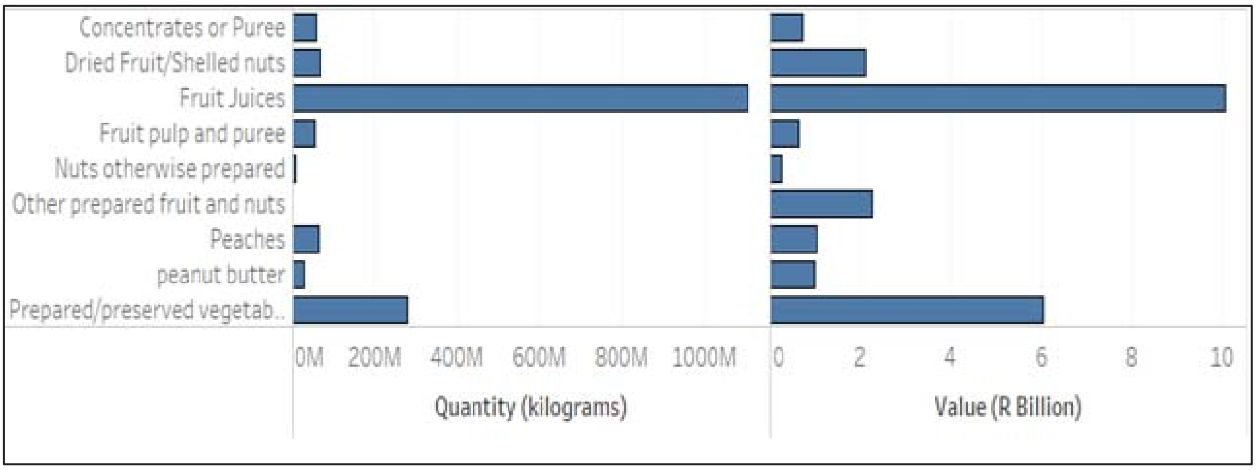

Figure 2.4: Production and income from fruit and vegetable processing in 2014 (Stats SA, 2016)

b. *Employment*

The FVPI provides direct employment to approximately 15 000 factory workers, but due to close linkages with the primary agricultural industry it may indirectly support many more individuals and households (Bekker, 2018). South African deciduous fruit farms alone account for over 107 000 permanent jobs, with approximately 429 485 dependants (Hortgro, 2017).

c. *Fruit inputs*

Excluding grapes and berries, it is estimated that over 1.18 million tons of fresh fruit was purchased for processing in 2017 (Bekker, 2018).

Deciduous fruit inputs

Deciduous fruit production occurs mainly in the Western Cape (Bekker, 2018) and in certain areas in the Eastern Cape, where warm dry summers and cold winters prevail (DAFF, 2017).

During the 2016/17 season, approximately 574 221 tons of deciduous fruit were utilised for processing. This amounted to a 1.5% decline from the 583 217 tons processed during the 2015/16 season (DAFF, 2017). Most of the fruit in the 2016/17 season was used for the production of fruit juice, with the exception of apricots and peaches, which were mainly canned (DAFF, 2017). The largest contributor of deciduous fruit were apples, with 318 448 tons purchased for processing in the 2016/17 season (DAFF, 2018). Of this, 98.9% was used for the production of juice, with the remaining 1.1% being canned (DAFF, 2017). The next biggest contributor was pears, with 154 940 tons purchased for processing (DAFF, 2018). Figure 2.5 shows the distribution of deciduous fruit used in processing.

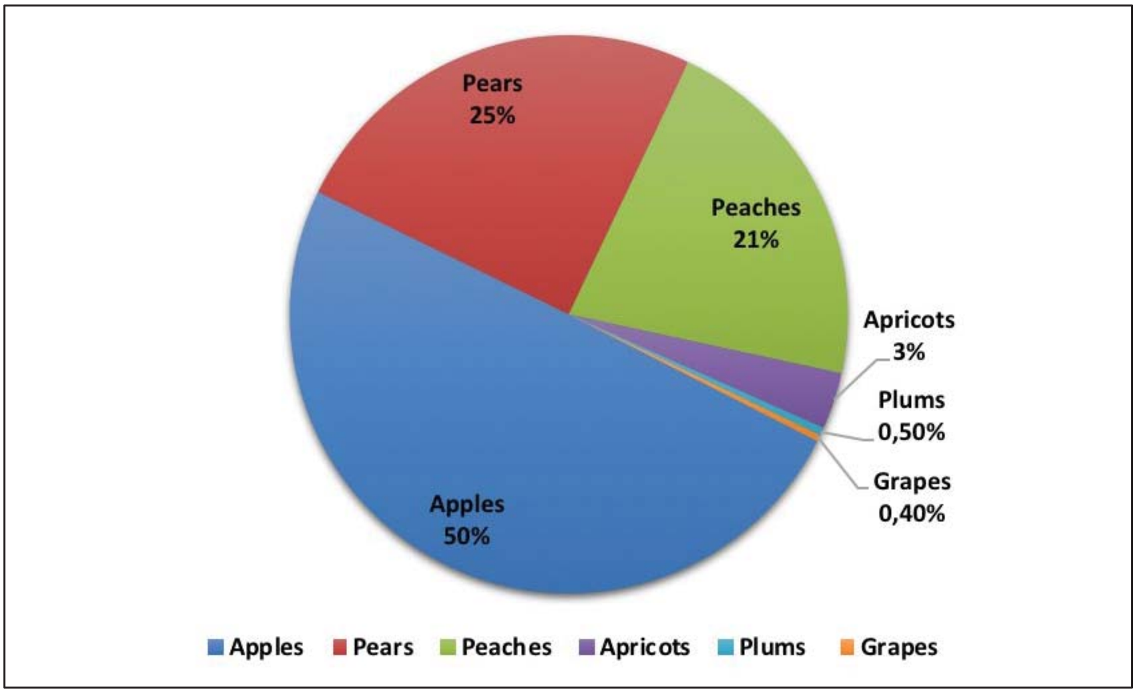

Figure 2.5: Deciduous fruit purchased for processing (DAFF, 2017)

Subtropical fruit inputs

Subtropical fruits require warmer conditions than deciduous fruits and are also sensitive to large temperature fluctuations and frost (DAFF, 2017). It is for this reason that cultivation of such fruit is only possible in certain regions of the country (DAFF, 2017). The most suitable regions are the northern provinces of Mpumalanga, KwaZulu-Natal, and Limpopo, but certain subtropical fruits like granadillas and guavas are also found in the Western Cape (DAFF, 2017). Pineapple production is concentrated in the border region of the Eastern Cape, with Summerpride Foods in East London operating the only large pineapple processing facility in the country (Bekker, 2018). It must however be noted that Swazican (a Rhodes Food Group subsidiary) in Eswatini (formerly Swaziland) manufactures and distributes canned pineapples to South Africa and abroad (Bekker, 2018). Figure 2.6 shows the relative contributions to the total of 132 392 tons of subtropical fruits processed for the 2016/17 year.

During the 2016/17 season, pineapples accounted for 48.4% of subtropical fruits used in processing, while mangoes contributed 25.2% and guavas 20.4% (DAFF, 2017). The quantities of avocados and pineapples used for processing during the 2016/17 season decreased by 30% and 19%, respectively (DAFF, 2017).

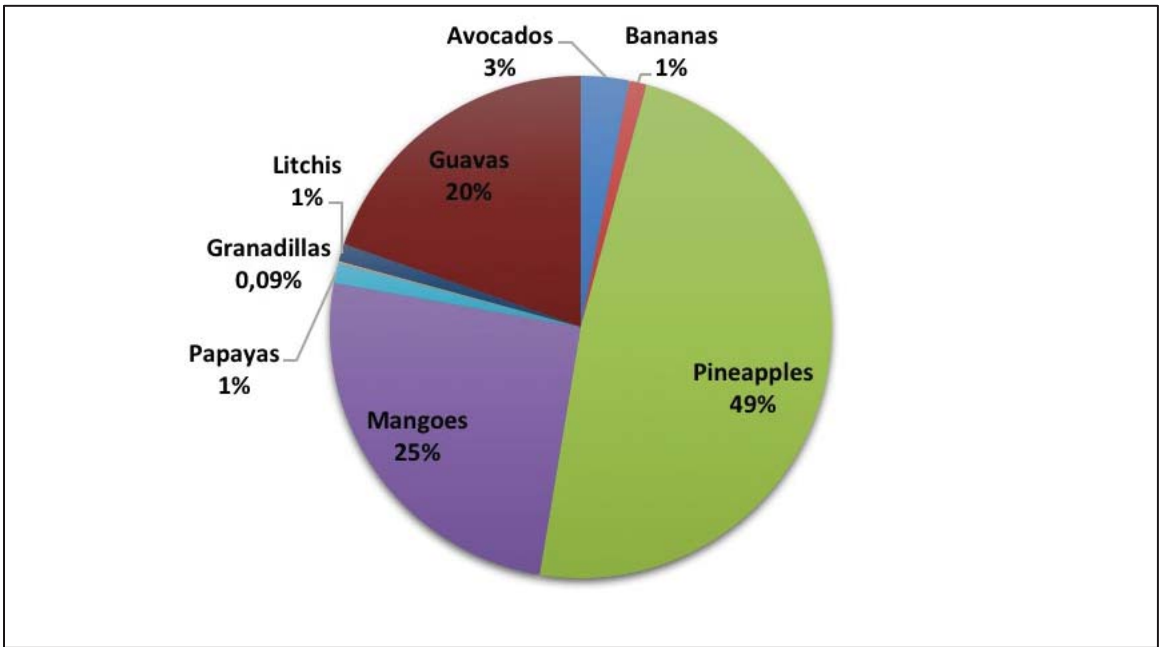

Figure 2.6: Subtropical fruits used in processing (DAFF, 2017)

Citrus inputs

Citrus fruit is grown mainly in Mpumalanga, Limpopo, the Eastern Cape, and Kwazulu-Natal provinces, where subtropical conditions (warm summers and mild winters) prevail, although it can also be found in the Western Cape (Bekker, 2018; DAFF, 2017). Citrus fruit used for processing amounted to 16.8% of total production in the 2016/17 season. A decrease in fruit purchased for processing of 44.4%, (682 000 tons in 2015/16 to 379

437 tons in 2016/17) was witnessed (DAFF, 2017). Oranges were the main citrus fruit used in processing, with a total of 195 436 tons (52% of total citrus fruits; DAFF, 2018).

Dried fruit inputs

South Africa's dried fruit comes mainly from the Orange River region in the Northern Cape (vine fruit) and the western and southern parts of the Western Cape (tree fruit; DAFF, 2017). Dried mangoes are also produced in Limpopo. By volume, the most important fruit varieties are Thomson's seedless grapes, unbleached sultanas, golden sultanas, currants, peaches, apricots, pears, and prunes (DAFF, 2017).

The total production of dried vine fruit increased by 20% to 65 589 tons in 2017, compared to 54 629 tons in 2016 (DAFF, 2017). The reason for this sharp increase in production was a likewise sharp increase in the demand for high-quality fruit (Dried Fruit Technical Services in DAFF, 2017). The amount of dried tree fruit produced was less impressive, with a decrease of 8.8% from 6 779 tons in 2016 to 6 181 tons in 2017 (DAFF, 2017).

d. Vegetable inputs

Vegetables are produced in most parts of the country, but certain areas tend to focus more on one specific type of vegetable. For example, green beans are grown predominantly in Kaapmuiden, Marble Hall, and Tzaneen; green peas mainly in George and Vaalharts; onions mainly in Pretoria, Brits, and Caledon; and asparagus mainly in Ficksburg and Krugersdorp (DAFF, 2017)

While specific data on quantities used for processing is not as readily available as for fruit, the DAFF (2017) does estimate that 9% (265 860 tons) of the total vegetable crop yield (excluding potatoes) is processed (Figure 2.7). This roughly corresponds to the SAFVCA's (South African Fruit and Vegetable Canners' Association) estimate of 200 000 tons being used for processing annually (SAFVCA in Bekker, 2018). Specific mention is made of onions, of which approximately 1% (or 5 524 tons) was processed during the 2016/17 season (DAFF, 2017). Of this volume, approximately 80% was canned and the remaining 20% was frozen (DAFF, 2017). Potatoes are South Africa's most economically important vegetable (UNIDO, 2017), accounting for 44% of the total vegetables produced during the 2016/17 season (DAFF, 2018).

There at 18 distinct potato-growing regions in South Africa, with the main production areas located in Mpumalanga, Western Cape, Limpopo, and the Free State (DAFF, 2017). Fresh potatoes are available all year round, as planting times differ between regions in response to climatic variation (DAFF, 2017). According to the DAFF (2017), approximately 18% of the total potato crop was processed in the year 2016. Of this, 91% was used for the production of potato chips and fries (both fresh and frozen), while the remaining 8% and 1% was frozen and canned, respectively (DAFF, 2017).

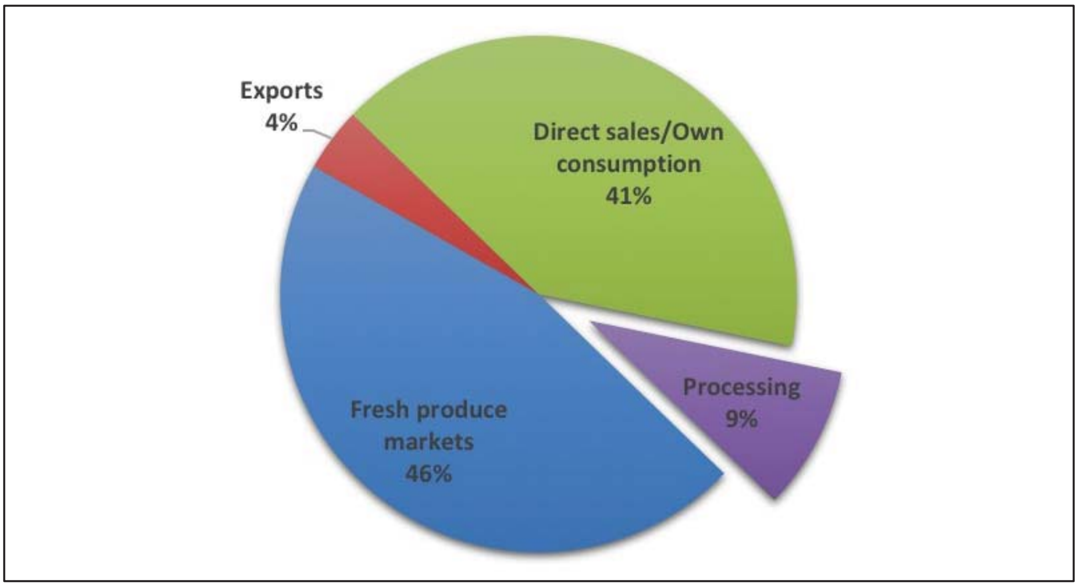

Figure 2.7: **Distribution channels for vegetables (excluding potatoes) in South Africa (DAFF, 2017)**

e. Locations of processing facilities

It is advantageous for a food processing facility to be close to a raw food production or supply area (Dauthy, 1995b; IPPC, 2006) especially regarding primary processing (Harcourt, 2011). This is to reduce damage to foodstuffs during transport and to allow for sufficient maturation before processing (Dauthy, 1995). It is also desirable for processing facilities to have free access to labour, adequate markets, and road or rail transport (Dauthy, 1995). In addition to this, it is especially advantageous for fruit and vegetable preservation installations to be close to receiving waters for the discharge of large amounts of treated wastewater (IPPC, 2006). In the South African context, fruit processing facilities tend to be concentrated in the areas of cultivation, whereas vegetable processing facilities seem to be closer to primary markets (Bekker, 2018).

Establishing a fruit and vegetable processing facility only makes economic sense when production can be maintained for many months at a time (Dauthy, 1995). To make this a reality, many processing facilities are required to process a variety of horticultural products (up to five) while accommodating a variety of processing techniques (for example, juicing, pulping, and canning; Dauthy, 1995). For ease of reference, Figure 2.8 shows the locations of verified processing facilities (as at April 2018). To simplify the classification of all these facilities, a distinction has been made not between vegetable or fruits, but rather the type of processing, namely the following:

- Canning/bottling
- Juicing (concentrate, pulp, and fresh juice)
- Drying
- Freezing

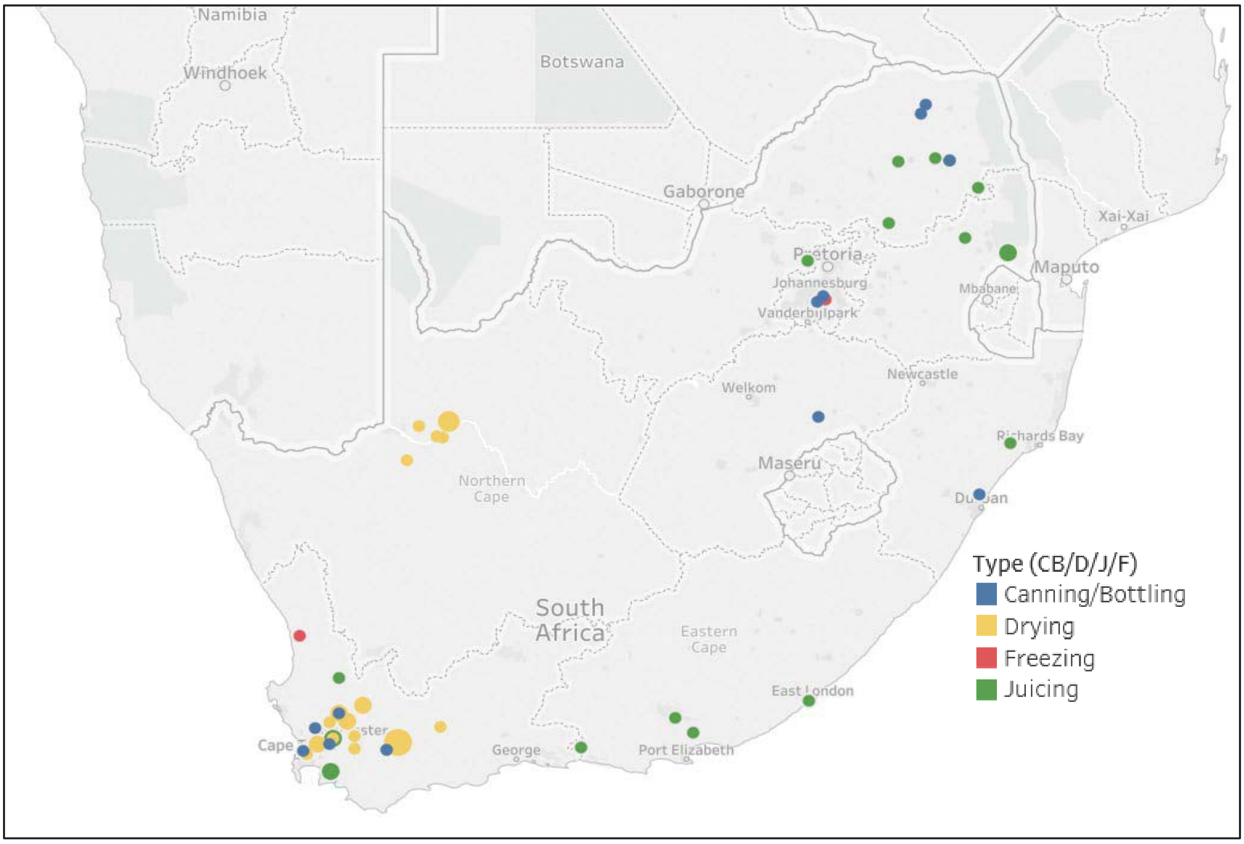

Figure 2.8: Locations of verified processing facilities in South Africa (current, as of May 2018)

f. Trade statistics

The Department of Trade, Industry and Competition (dtic) maintains a very comprehensive database on exports and imports, and classifies all goods according to the Harmonized System (HS) used globally (dtic, 2018). The purpose of this nomenclature is to allow for classification of traded goods on a common basis for customs purposes (UN Trade Statistics, 2010). Figure 2.9 shows imports and exports of processed fruit and vegetables (Code H20: Preparations of vegetables, fruit, nuts or other parts of plants) for South Africa from 1992 to 2017, normalised according to 2010 as the base year (dtic, 2018). It is interesting to note that from 1992 to the present, processed fruit and vegetables have maintained a positive trade balance, making the industry a net earner of foreign exchange for at least the past 25 years. Exports reached a maximum value of ZAR 5.803 billion in 2016 (2010 base year; dtic, 2018). The slight drop in exports that can be seen at the terminal end of Figure 2.9 (2016) may be as a result of drought and various currency fluctuations (Bekker, 2018).

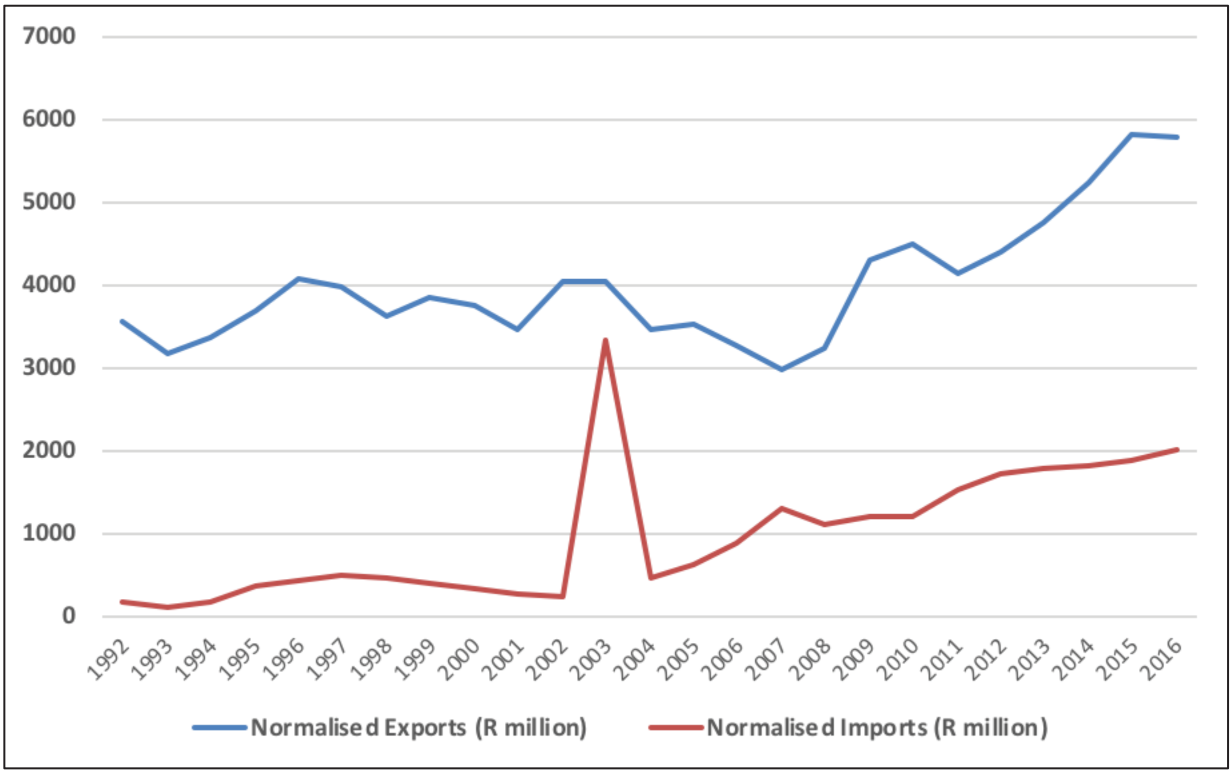

Figure 2.9: Value of trade in processed fruit and vegetables, with 2010 as the base year (dtic, 2018).

According to the SAFVCA in Bekker (2018), approximately 80% of South African canned and processed fruit is destined for export. This is in stark contrast to processed vegetable products, of which only 10% is exported, and even that is mainly to regional African trade partners (Bekker, 2018). Data from the dtic (Figure 2.10 and Figure 2.11) lends much support to this claim.

Figure 2.10 shows the contributions of the nine product categories within the H20 category, with Table 2.1 providing a detailed description of each HS code. Products in the H2008 (fruit, nuts, and other edible parts of plants, otherwise prepared or preserved) and H2009 (juices) categories made up the majority (75%) of exports of total processed fruit and vegetables in 2017 and therefore warrant further investigation. The two clear leaders were mixed juices and processed peaches/nectarines, with an export value in 2017 of ZAR 1.06 billion (nominal) , and ZAR 915 million (nominal), respectively (DTI, 2018). Also of interest is that the prepared peaches/nectarine category enjoyed the leading position until 2009, when it was overtaken by mixed juices (Figure 2.11).

Table 2.1: HS codes defined (dtic, 2018)

HS	Description
H2001	Vegetables, fruits, nuts, and other edible parts of plants, prepared or preserved by vinegar or acetic acid
H2002	Tomatoes prepared or preserved, but not by vinegar or acetic acid
H2003	Mushrooms and truffles prepared or preserved, but not by vinegar or acetic acid
H2004	Other vegetables prepared or preserved, but not by vinegar or acetic acid, and frozen
H2005	Other vegetables prepared or preserved, but not by vinegar or acetic acid, and not frozen
H2006	Vegetables, fruits, nuts, fruit peels and other parts of plants, preserved by sugar (drained, glacé, or crystallised)
H2007	Jams, fruit jellies, marmalades, fruit, or nut purées and fruit or nut pastes, obtained by cooking
H2008	Fruits, nuts and other edible parts of plants, otherwise prepared or preserved
H2009	Fruit juices (including grape must) and vegetable juices, unfermented and not containing added spirits

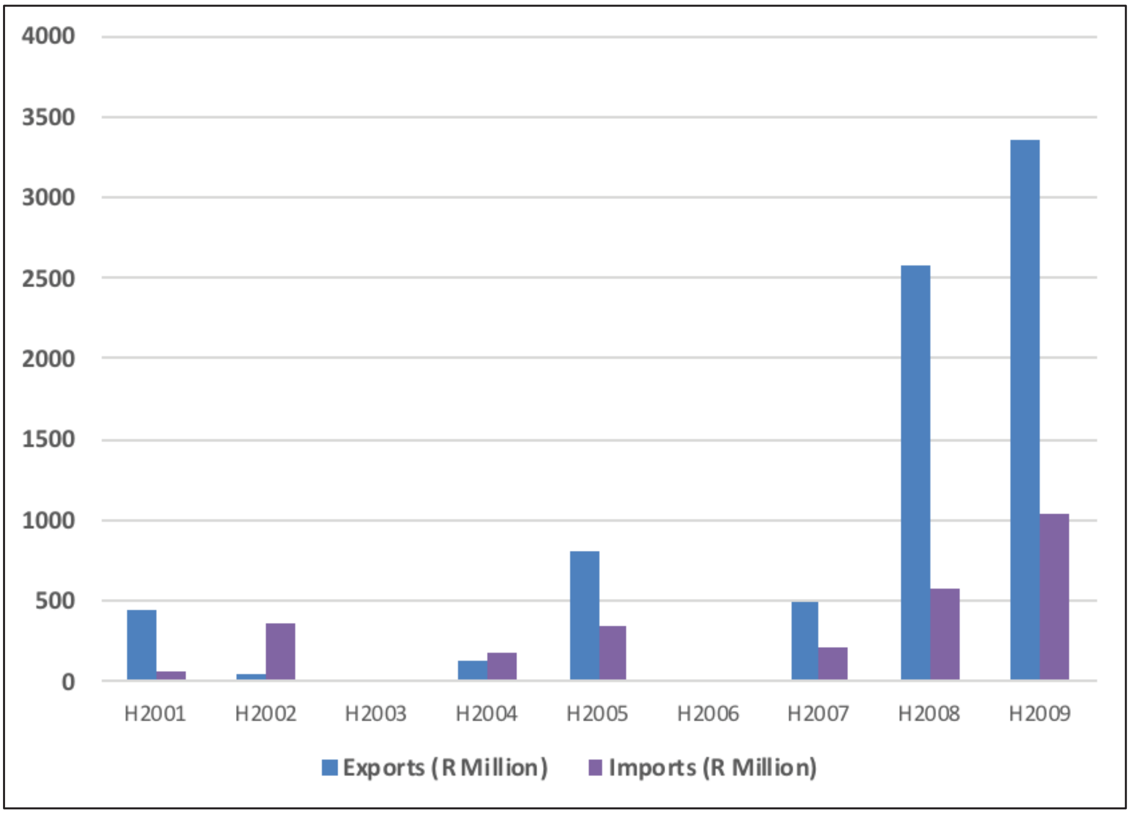

Figure 2.10: **Imports and exports of processed fruit and vegetables in 2017 (dtic, 2018)**

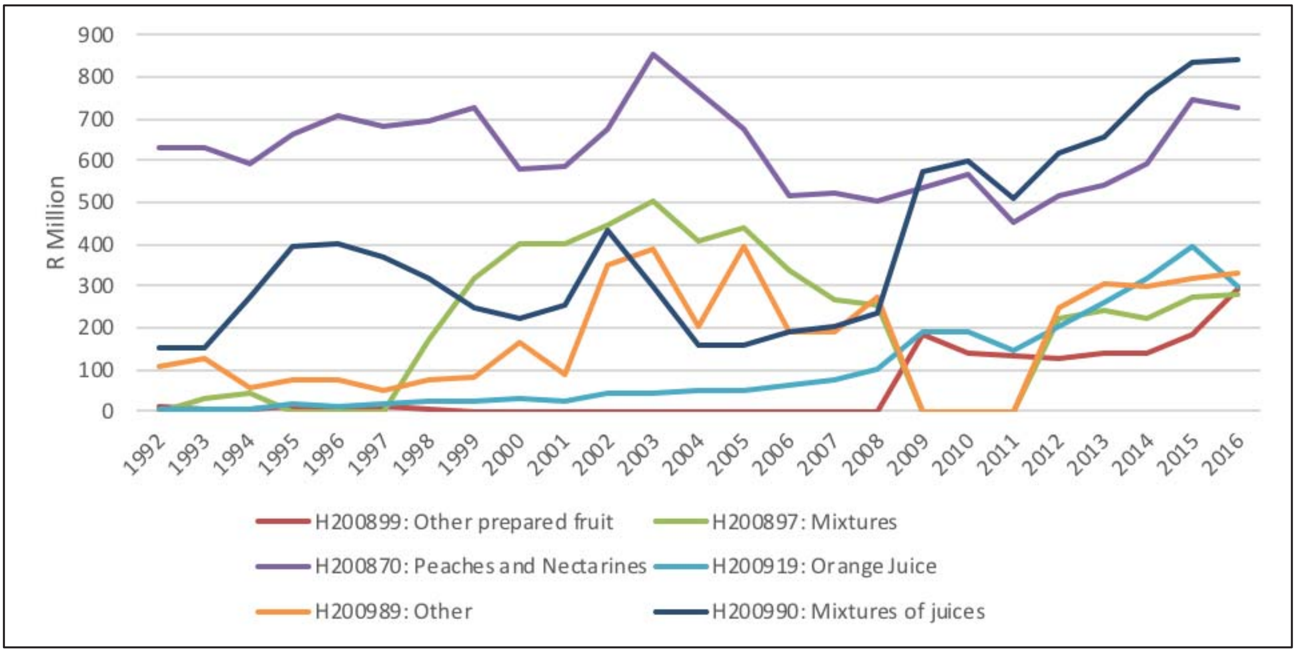

Figure 2.11: **Change in the total value of exports, from 2010 as base year (dtic, 2018)**

With regards to export destinations (Figure 2.12), it is interesting although not surprising to note that exports to the the rest of Africa are in the lead, at almost 49% of total exports. The SA SAFVCA and the SAFJA also continue to identify the continent as an important export region (Bekker, 2018). Europe follows at 26% – more than double that of North America, Oceania, and South America at collectively 10.45% (CID, 2018). Within the main export region (Africa), it is found that the immediate neighbours of South Africa – namely Namibia, Botswana, and Mozambique – lead with 9.76%, 9.75%, and 4.95%, respectively (CID, 2018). This is not surprising, as Namibia and Botswana form part of the Southern African Customs Union (SACU), which together with the other member states (South Africa, Lesotho, and Swaziland) aims to facilitate the cross-border movement of goods between member countries (SACU, 2013). The main European export destinations are the Netherlands (8.6%) and Germany (6.13%; CID, 2018).

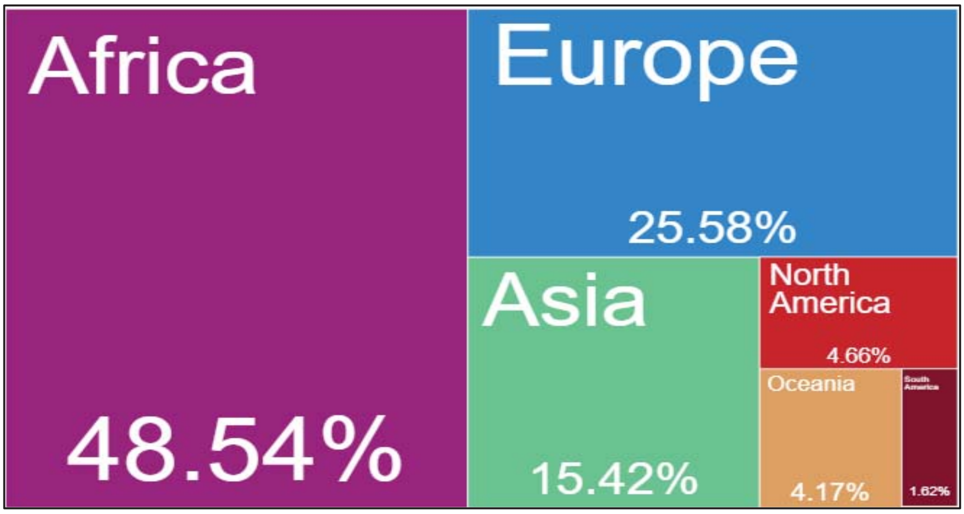

Figure 2.12: Export destinations for fruit and vegetable products in 2016 (CID, 2018)

g. Economic outlook

Bekker (2018) has detailed the various challenges facing the industry at present, with commentary well summarised in the form of a strengths, weaknesses, opportunities, and threats (SWOT) analysis. The details of this SWOT analysis are presented in Table 2.2.

Table 2.2: SWOT analysis of the South African FVPI (Bekker, 2018)

Strengths	Weaknesses
• Well-established international trade network • Increasing processing capacity • Counter seasonality to export destinations • Proximity to African export markets • Industry has been targeted for governmental support	• Substantial barriers to entry • Susceptible to drought and fluctuations in horticultural yield • Profitability very dependent on exchange rate • Consumer spending constraints may lead to substitution with fresh produce • Increasingly concentrated and mature sector
Opportunities	**Threats**
• Increasing export opportunities (especially Asia) • Increased regional demand for processed fruits and juices • Potential support from government in the form of funding and linkage schemes	• Slow economic growth and high unemployment will pressure consumer spending • Drought and water shortages • Rising input costs (including labour, energy, and fuel) • Unreliable electricity supply • Unreliable transport network • Sugar Sweetened Beverages Levy (SBL; Health Promotion Levy) • Carbon tax • Concerns over expropriation without compensation

2.4 CHANGES TO THE SOUTH AFRICAN FRUIT AND VEGETABLE PROCESSING INDUSTRIES IN THE PAST 32 YEARS

The evolution of treatment technologies applied in the processing of fruit and vegetables is evident when comparing the recommendations of the original NATSURV to those found in more up-to-date documents, such as the guideline provided by the European International Pollution Prevention and Control (IPPC) bureau in 2006. The NATSURV conducted in 1987 merely recommended the construction of facilities to separate processes where wastewater is generated from those where it is not. In addition to this, they also suggested applying either a filtration or sedimentation step to separate solids from the wastewater. The IPPC (2006) expands on a variety of technologies deemed suitable for wastewater treatment within the FVPI.

Table 2.3 shows the main fruit and vegetable processing industries in South Africa (as at 2019), as well as their locations.

Table 2.3: Fruit and vegetable processing industries in South Africa and their locations (as in 2019)

Associated Fruit Processors	Grabouw
Ashton/Langeberg	Ashton
At Source (Pty) Ltd	Ceres
Baby Food Company	Cape Town
BM Food Manufacturers	Cape Town
Bio-Select	Bronkhorstspruit
Boland Pulp (Rhodes)	Wellington
Blue Skies	Balfour
Bronpro	Nelspruit
Cape Dried Fruit (Eiendoms) Bpk	Montagu
Cape Fruit Processors	Malalane
Cape Fruit Processors	Paarl
Cape Fruit Processors	Kirkwood
Cape Fruit Processors	Hoedspruit
Cape Fruit Processors	Citrusdal
Carara Agro Processing	Grahamstown
Carpe Diem Raisins CC	Upington
Ceres Fruit Processors	Ceres

Darsot Food Corporation	Eikenhof
Dried Fruit Direct Marketing (Edms) Bpk	Prince Alfred Hamlet
Deemster (Rhodes)	Bethlehem
Dynamic Commodities	Port Elizabeth
Elandsrivier Boerdery (Edms) Bp	Prince Alfred Hamlet
Elgin Fruit Juices (Pty) Ltd	Grabouw
Elvin Food and Beverages (Libstar)	East London
Farmers Pride Raisins	Upington
Fruitlips	Piketberg
Fruits Du Sud (Pty) Ltd	Kanoneiland
Fruitworks (Pty) Ltd	Paarl
Giants Canning	Johannesburg
Golden Pine Products	Louis Trichardt
Grannor Passi	Polokwane
Grannor Passi	Letsitele
Grannor Passi	Louterwater
Grannor Passi	Marble Hall
Grassroots Group (Pty) Ltd	Gouda
Henties	Saxenburg
In2Juice	Cape Town
Just Veggies	Vryheid
Kambrosig Tien	Wellington
Koo Droëry (H/A Jakkalsvlei)	Montagu
Lamberts Bay Food	Lambert's Bay
Langeberg & Ashton Foods	Ashton
Letaba Citrus Processors	Tzaneen
Little Oaks Droëvrugte	Montagu
Locarno Sun Dried Fruit CC	Montagu
Magalies Citrus	Brits
McCain	Delmas

Mebos Boerdery Bk	Tulbagh
Miami Canners	Letsitele
Montagu Droëvrugte (Eiendoms) Bpk	Montagu
Montagu Foods (Libstar)	Montagu
Murludi	Tulbagh
Nature's Garden	Alberton
Nkwaleni Processors	Nkwaleni
Northern Cape Raisins (Pty) Ltd	Kakamas
Onderberg	Malalane
Orange River Concentrate	Upington
Pacmar (Rhodes)	Wellington
Peppadew International	Tzaneen
Philmar Driedfruit	Ladysmith
Pioneer Foods	Malmesbury
Prosperitas Foods	Upington
Rainbow Fruit Pty Ltd	Paarl
RedSun Dried Fruit & Nuts Pty Ltd	Keimoes
Rhodes	Machado
Rhodes	Bethlehem
Rhodes	Verulam
Rian Botha	Worcester
Rugani	Krugersdorp
Richter's Veg Crisps	Piketberg
SAD, Pioneer Foods	Cape Town
SAD, Pioneer Foods	Upington
Shelford Jams and Juices	East London
Skoonuitsig Vrugte	Breërivier
Summerpride Foods	East London
The Raisin Company	Marchand
Tiger Brands	Paarl

Tiger Food Brands Ltd	Ashton
Venco Fruit Processors	Addo
Zulu Fruit	Ceres
Westfalia	Cape Town

CHAPTER 3: FRUIT AND VEGETABLE PROCESSING PROCESSES

This chapter presents a brief overview of the processes and practices used in the fruit and vegetable processing industry. The intention is that it will provide a broad understanding – particularly of where and how water is used in the processes and/or where and how wastewater is generated.

3.1 PRESERVATION AND PRACTICAL PROCESS APPLICATION

Dauthy (1995) found that with a knowledge of the specific deterioration properties of foods, it is possible to list a variety of biological, physical, and chemical methods that may be used in the preservation of the material in question (Table 3.1).

Table 3.1: Technical means of preservation in foods (Dauthy, 1995)

Descriptor	Parameter
Physical	Heating
	Cooling
	Lowering of water content
	Sterilising filtration
	Irradiation
	Other (inert gases, vacuum, high pressure)
Chemical	Salting
	Addition of sugar
	Artificial acidification
	Ethyl alcohol addition
	Antiseptic substances
Biochemical	Lactic fermentation
	Alcoholic fermentation

It must however be noted that the classification of processing procedures may be difficult, as their effects are often a combination of biochemical, chemical, or biochemical phenomena (Dauthy, 1995). Due to technical-economic considerations as well as changes to nutritional and organoleptic properties, not all of the technical processes listed in Table 3.1 would be suitable for fruit and vegetable processing (Dauthy, 1995). Of the many possible ways of preventing deterioration, specific techniques have been found most appropriate for preserving fruit and vegetables (Table 3.2).

For the purposes of further discussion, it is necessary to condense the preservation techniques described in Table 3.2 into generic processing practices most commonly encountered in the South African situation. This is necessary for two reasons. Firstly, many of the procedures occur in tandem when generic processing techniques are regarded. For example, juicing often involves pasteurisation and chemical preservation (by adding preservatives like sulphur dioxide). Therefore, looking at a more generic process like juicing will by its very nature deal with more specific principles. Secondly, to investigate individual procedures would be beyond the scope of this study, as the investigation is primarily concerned with water use in the processes, and not necessarily the principles themselves.

Table 3.2: Practical processing applications for fruit and vegetables

Process	Practical applications
Fresh storage	Fruits & vegetables
Cold storage	Fruits & vegetables
Freezing	Fruits & vegetables
Drying/dehydration	Fruits & vegetables
Concentration	Fruits & vegetable juices
Chemical preservation	Semi-processed fruit
Addition of sugar	Fruit products & preserves
Pasteurization	Fruit and vegetable juices
Sterilisation	Fruits & vegetables
Sterilising filtration	Fruit juices
Irradiation	Fruits & vegetables

3.2 JUICING

Firstly, fresh fruit is subjected to a preparation procedure where the fruit is graded and washed, and the stems are removed. The fruit is also subjected to a manual selection procedure where rotten fruit and other undesirable components are discarded (Horvath-Kerkai, 2006). The next step is the chopping and subsequent preparation of the fruit, which may involve further mechanical manipulation, heating, and addition of enzymes (Horvath-Kerkai, 2006). A common practice in industry is the use of cellulases and pectinases (Dauthy, 1995; Sharma et al., 2017). Using enzymes in combination increases the juice yield, clarity, and TSS – while also decreasing viscosity and turbidity (Sharma et al., 2017). After that, the actual liquid extraction occurs, with the most common method being pressing (Horvath-Kerkai, 2006). The pressed juice is then subjected to a clarification step (if a cloudy juice is not desired), which involves a physiochemical (usually a combination of mineral clarifying agents and enzymatic treatments) and/or mechanical procedure (centrifugation or membrane filtration; Horvath-Kerkai, 2006). A shift to membrane technology is currently underway, due to the negative effects of temperature on fruit juice quality, as well as savings on operating costs and manpower that may result

(Bhattacharjee et al., 2017). A problem with membrane treatment (especially with microfiltration and ultrafiltration), however, is that of fouling – which reduces permeate flux and membrane lifespan (Bhattacharjee et al., 2017).

The cloudy or clarified juice can now be either packaged directly or concentrated to extend its shelf life and improve storage and/or transport properties (Horvath-Kerkai, 2006). Concentration can be accomplished by three methods: evaporation, freeze concentration, and membrane processes – each with their own particular advantages and disadvantages (Fellows, 2009b; Horvath-Kerkai, 2006). Freeze concentration is used mainly for high-quality fruit juice due to its ability to preserve the organoleptic properties of the product, despite the fact that capital, energy, and operating requirements are generally higher (Fellows, 2009b). When final packaging takes place, the juice (or reconstituted concentrate) is heated to a temperature of 82–85°C, after which it is placed in a suitable container (typically glass or plastic). High temperature, short time (HTST) pasteurisation is the most commonly used industrial technique for juice products (Koutchma et al., 2016).

An important factor to consider when manufacturing vegetable juice is that the pH is often greater than 4.5, meaning that a full sterilisation treatment is necessary (IPPC, 2006). A treatment with mild organic or inorganic acids may lower the pH sufficiently to allow for a less intense treatment such as pasteurisation, although blending with high-acidity juices (e.g. tomato, citrus, or pineapple) may provide a similar effect (IPPC, 2006). Another widely used approach is spray drying of fruit and vegetable juices (Shishir and Chen, 2017). The key driver for this processing technique is the reduction in transport, storage, and packaging costs – as well as the improvements in shelf life that are made possible by the high stability of the powder (Shishir and Chen, 2017).

When considering the water use within a typical operation, using apple and pear juicing as an example, water use is split between process water, boiler feed water, and washdown/domestic water requirements (Binnie and Partners, 1987). Process water accounts for 20% of the total consumed water, and boiler feed/steam raising for 4%. Washdown of the pressing plant forms 20% of the total, while other general washing and domestic operations make up the remaining 56%.

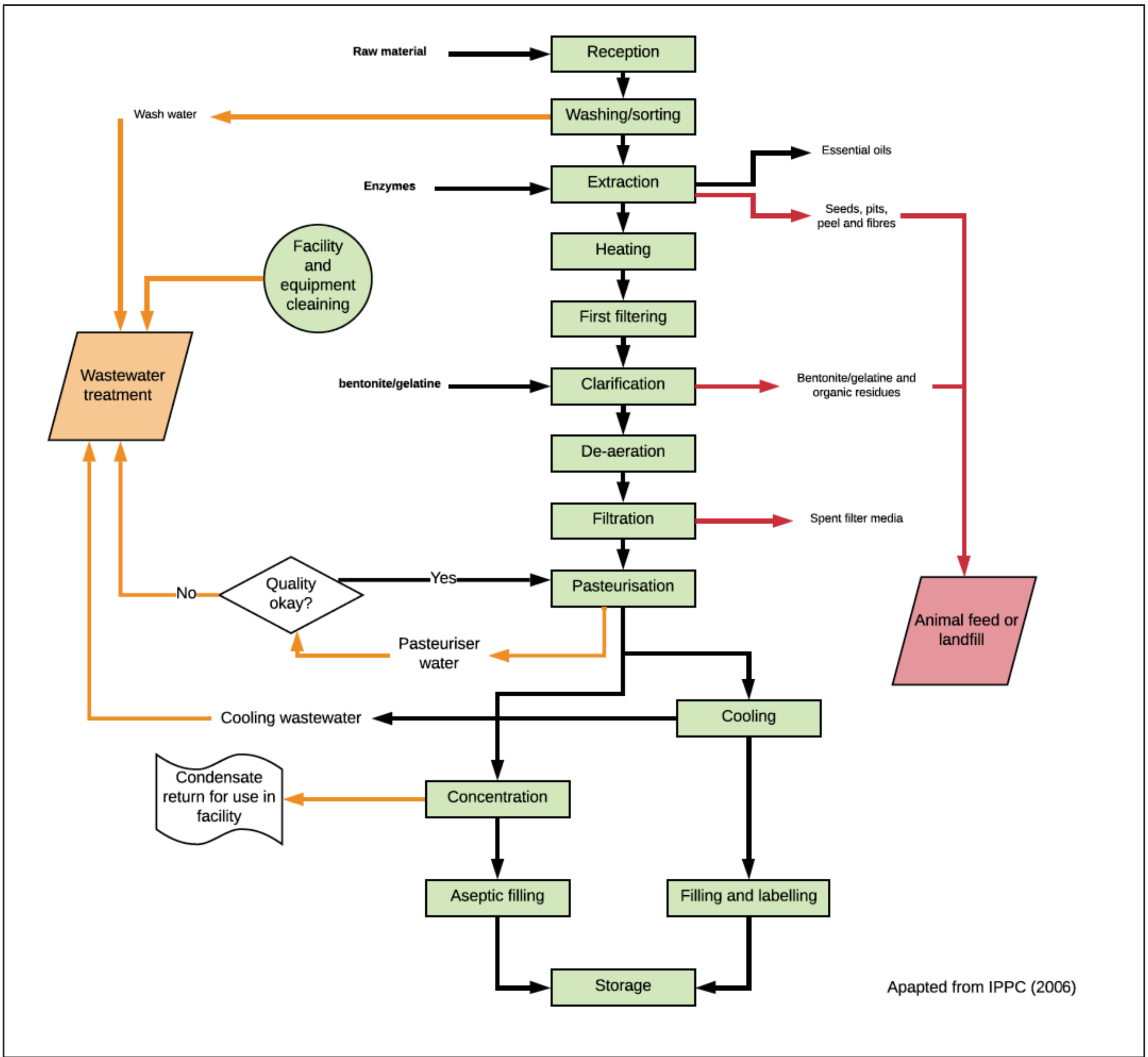

Figure 3.1: Process-flow diagram for juicing industries (adapted from IPPC, 2006)

3.3 CANNING

Fruit for canning should ideally be used as soon as possible after delivery, although at times it may have to be stored under chillded conditions for extended periods (IPPC, 2006). The fruit is first washed and then sorted, after which it is cored or pitted before peeling. There are a variety of peeling techniques, of which caustic, mechanical, steam, and abrasive peeling are the most common. Peeled fruit may then be transferred to tanks containing either brine or ascorbic acid to prevent browning. The fruit may then be sliced before being placed in containers with either a syrup or natural juice. Before being sealed, the container may be slightly heated or subjected to a brief steam treatment in the headspace, in a procedure known as 'exhausting' – which is done to create a negative pressure gradient within the container (IPPC, 2006). Taking apricots as an example, pasteurisation processes should then seek to raise the temperature of the centres of the product to a minimum of 90.5 °C. (Lopez, 1981, in Siddiq, 2006).

Valta et al. (2017) have found that of the main activities using water in plants producing canned peaches and apricots, 40% is related to cutting and pitting, 35% to pasteurisation, and the remaining 25% to peeling and transfer. One plant that cans peach and apricot compote indicated that the main activities in which water is used in the process of manufacturing of canned peaches and apricots are pasteurisation (44%); washing and transfer (38%); and steam production, cleaning, and staff needs (18%).

3.4 FREEZING

Fruits are commonly frozen when further processing (e.g. manufacturing of preserves) is likely to occur (IPPC, 2006). Different freezing techniques are used for different products (De Ancos et al., 2006) and are categorised according to the heat-transmission mediums used (Rahman and Velez-Ruiz, 2007), which include the following:

1. **Freezing by contact with a cooled solid (plate freezing)**: The product to be frozen is sandwiched between two cooled plates. When freezing is completed, hot water is circulated around the edges to break the ice seal. This technique is only suitable for regular-shaped products.
2. **Contact with a cooled liquid (immersion freezing)**: Food is submerged in a low temperature brine to ensure a rapid temperature reduction by means of direct heat exchange. Whole fruits, tomato slices, and orange segments are examples of products that can be frozen in this way.
3. **Freezing by contact with a cooled gas**: Cold air can be circulated around a product placed on a tray within an enclosed space (*cabinet cooling*). Another method is *air blast freezing*, where the product is cooled by high-speed cooled air (2.5–5m.s^{-2} for most economical freezing).
4. **Cryogenic freezing:** An extremely rapid method whereby products are placed in direct contact with liquified gases, usually nitrogen or carbon dioxide. Due to the high cost of gas compression, this technique is typically used for high-value products. It is also not recommended for large, whole fruits (e.g. prunes and peaches) – due to the risk of crushing (De Ancos et al., 2006)

A Greek fruit freezing facility studied by Valta et al. (2017) used most of its water (67%) in the actual freezing process, followed by the washing (13%), bleaching (12%), and slicing (8%) processes.

3.5 FRUIT PRESERVES

Preserving can be defined as the manufacturing of jams, jellies, and marmalades – products for which South African legislation prescribes standards (refer to the APS regulation). Standards for jams and marmalades are similar to those for jellies, except that instead of fruit juice, whole fruits are added and the minimum SS contents are slightly higher (68% for some and 65% for others; Vibhakara & Bawa, 2006). The manufacturing process commences with the selection of the raw ingredients. Fruit used in the manufacturing of jams should be fully matured, rich in flavour, and of a suitable texture, while those used for jellies should contain sufficient pectin and acid.

Other typical ingredients of the preserving processes are sweetening agents (typically cane or beet sugar; Dauthy, 1995), an acid (typically citric or malic acid), buffers (such as trisodium citrate), gelling agents (usually pectin), anti-foaming agents, and citrus peel in the case of marmalade (IPPC, 2006). Generally, fruits are then washed to remove all dirt and foreign debris and then pitted and/or peeled as required. The combination of fruit and other ingredients is then boiled to create a pectin, acid, and sugar union. Although arguably one of the most important steps in the process, boiling should be as short as possible to avoid a loss of flavour and/or colour and prevent the hydrolysis of the pectin (which could lead to jelly failure; Vibhakara & Bawa, 2006). The syrup is then hot-filled in jars and hermetically sealed with metal caps featuring a rubber gasket. The container is then cooled to 21ºC to allow the setting of the pectin (Vibhakara and Bawa, 2006).

3.6 DRYING

The aim of drying is to reduce the water activity (a_w), which is necessary to inhibit the deteriorative action of microorganisms and enzymes associated with the food product (Dauthy, 1995; Fellows, 2009b). To achieve this, various techniques may be used, although the most common method still remains sun drying (Fellows, 2009a). The basic sun drying process involves sorting, grading, washing and dipping, drying and, finally, packing. Some fruits are also sulphited before drying in order to protect them from mould, as well as to soften the tissue that in turn leads to faster drying (IPPC, 2006). In some cases, after harvesting, the fruit is dipped in or sprayed with a solution of potassium carbonate that also contains dipping oil (IPPC, 2006). Sun drying has its limitations, which include spoilage due to adverse climatic conditions and the loss of product due to animals, insect infestations, and fungal growth (Vijayavenkataraman et al*.,* 2012). The process is also labour intensive and time consuming, while also requiring a large surface area (Vijayavenkataraman et al., 2012).

Within the industrial food processing environment, conventional hot air dryers (HADs) are the mainstay technology, despite their high energy requirements (Michailidis and Krokida, 2015). Freeze drying is the most versatile operation, although its application is limited to high-value products – as a result of the high cost associated with high vacuum creation and the freezing of raw materials (Michailidis and Krokida, 2015). Therefore, taking the drawbacks of solar and mechanical (industrial) techniques into account, sun drying has been proposed as a compromise (Vijayavenkataraman et al., 2012). The technique offers lower fossil fuel consumption when compared to purely mechanical processes and a higher-quality product, with fewer losses when compared to sun drying (Vijayavenkataraman et al., 2012).

The CLFP (2015), in its study of industrial dehydration facilities, found that half of its total water requirement was for the washing of raw products, while the other half was used for sanitation purposes.

The main potato products processed in South Africa are chips (fries) and crisps (91%; DAFF, 2017), with both produced through similar manufacturing processes (IPPC, 2006). The basic procedure consists of peeling, slicing to desired size, blanching, and frying to achieve the desired sensory properties (IPPC, 2006).

Deep-fat frying is a process that involves simultaneous mass and heat transfer while the food sample is submerged in oil (Pedreschi & Enrione, 2014). The oil allows for the rapid transfer of heat into the food, which vaporises the inherent moisture and drives it to the surface and later into the surrounding oil (Pedreschi and Enrione, 2014). A certain amount of oil is also absorbed by the sample itself (Pedreschi et al*.,* 2012). The frying process also allows for the reaction between reducing sugars and amino acids which leads to browning and textural changes as well as softening at the beginning of the process, with the surface hardening towards the end (Pedreschi and Enrione, 2014). However, the frying process is also known to form heat-induced toxins (e.g. acrylamide and furan; Pedreschi and Enrione, 2014).

Frying pyrophosphate and sodium metabisulphite are common ingredients used to prevent the discolouring of potato products, with pyrophosphate in particular being prevalent in waste streams of the processing facilities (IPPC, 2006).

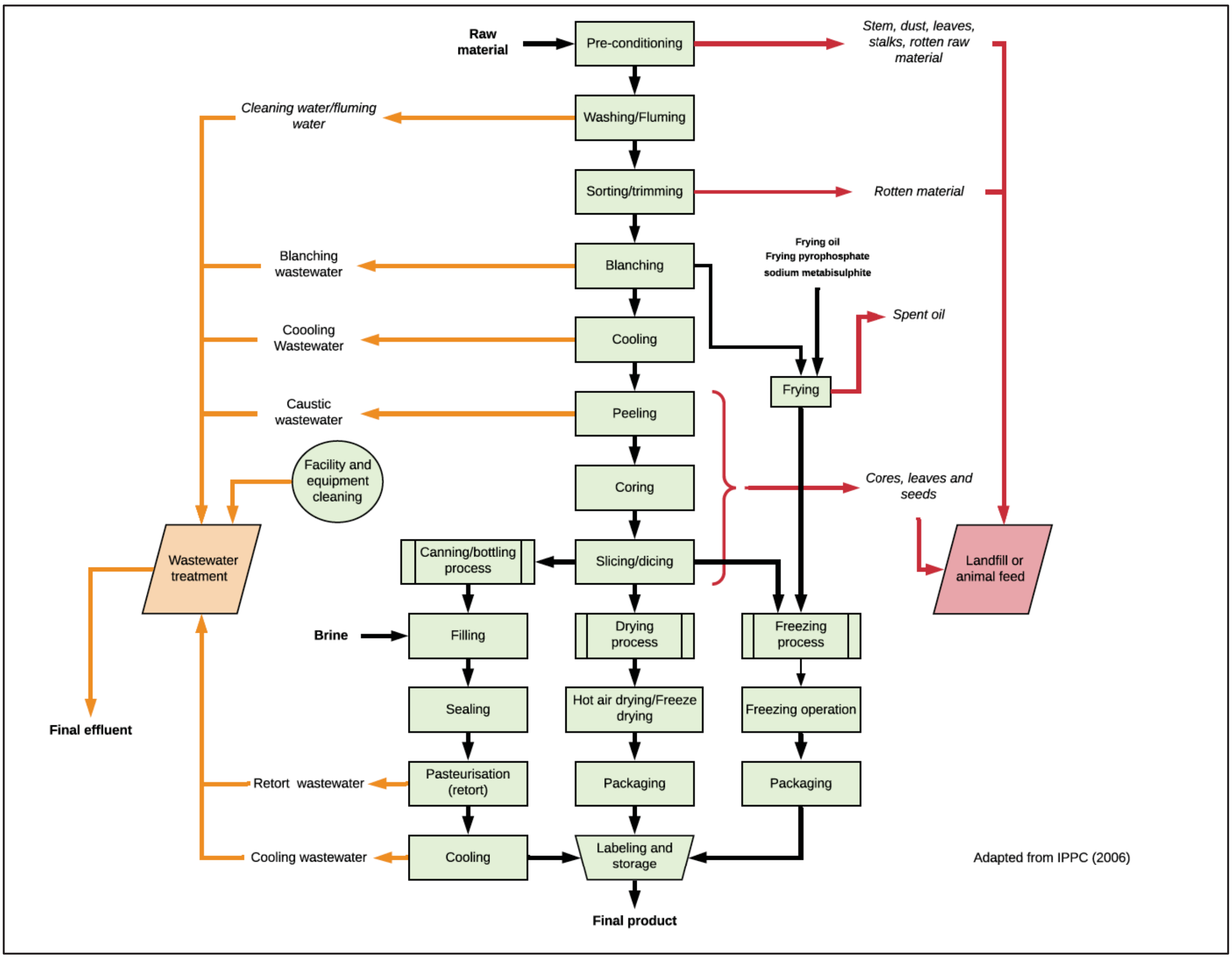

Figure 3.2: Process flow diagram for the canning, freezing, and drying industries *(*adapted from IPPC, 2006*)*

CHAPTER 4: WASTEWATER AND EFFLUENT LEGISLATION

4.1 NATIONAL ACTS

The Constitution of the Republic of South Africa Act 108 of 1996 (Constitution) states that everyone has the right to an environment that is not harmful to his or her health or well-being (Republic of South Africa, 1998). This includes the right to environmental protection for the benefit of present and future generations, through reasonable legislative and other measures to prevent pollution and ecological degradation, promote conservation, and secure ecologically sustainable development and use of natural resources. These rights must be balanced with the promotion of justifiable economic and social development. Regulations that ensure these rights falls under the jurisdiction of the Department of Environmental Affairs (DEA). The Bill of Rights in the Constitution enshrines the concept of sustainability. Rights regarding the environment, water, access to information, and just administrative action are specified in the act.

These rights and other requirements are further legislated through the National Water Act 36 of 1998 (NWA). The NWA provides the legal basis for water management in South Africa by ensuring ecological integrity, economic growth, and social equity when managing water use. Other legislation relevant to the food and vegetable processing industry are the National Environmental Management Act 107 of 1998, the National Environmental Management: Waste Act 59 of 2008, and the National Environmental Management: Air Quality Act 39 of 2004. Broadly speaking, these acts outline the requirements for the storage and handling of waste on-site, licensing requirements, the establishment of waste management plans, the setting of limits for air emissions, and the setting of penalties for offences.

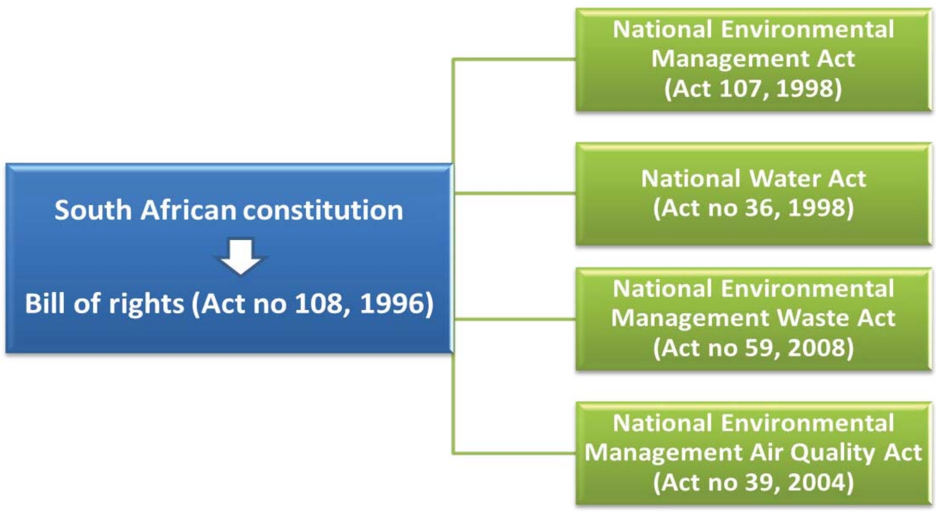

Figure 4.1: National environmental and water policies relevant to the fruit and vegetable processing industry (authors' own illustration)

The NWA introduced the concept of Integrated Water Resource Management (IWRM), which provides for water resource- and source-directed measures to manage the aquatic environment. Resource-directed measures aim to protect and manage the environment that receives water, while source-directed measures aim to control the impact on the receiving environment by preventing pollution, reusing water, and treating wastewater. The integration of resource- and source-directed measures forms the basis of the hierarchy of decision-making aimed at mitigating the effect of generated waste. This hierarchy is based on a precautionary approach; the order of priority for water and waste management decisions and/or actions is shown in Figure 4.2.

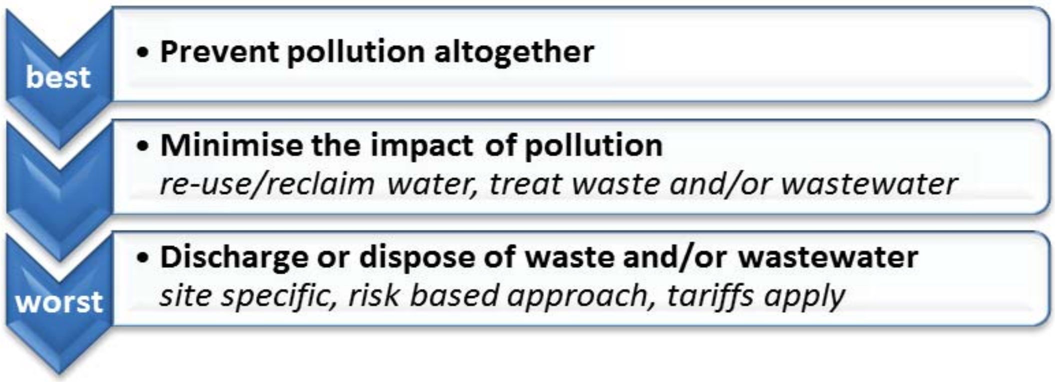

Figure 4.2: Hierarchy of decision making intended to protect the environment

4.1.1 Water acts

The Department of Water and Sanitation (DWS) – formerly the Department of Water Affairs (DWA) – and the Department of Water Affairs and Forestry (DWAF) are the two main government authorities heading the governance of the water resources and sanitation sector in South Africa. The DWS is the custodian of South Africa's water resources and implements the NWA and the Water Services Act 108 of 1997 (WSA). The DWS is also the national regulator of the water services sector.

The NWA provides the legal framework for the effective and sustainable management of water resources within South Africa. The act aims to protect, use, develop, conserve, manage, and control water resources as a whole, promoting the integrated management of water resources with the participation of all stakeholders. The act stipulates the requirements for, among others, the development of a national water strategy and catchment management agencies, the protection of water resources through classification, setting reserves (for basic human needs and ecological purposes), determining resource quality objectives, promotion of pollution prevention, and the provision of penalties for non-compliance.

The WSA deals mainly with water services or potable (drinkable) water and sanitation services supplied by municipalities to households and other municipal water users. It contains rules about how municipalities should provide water and sanitation services. Within each municipal area, by-laws are developed that outline the water supply and effluent discharge regulations and tariffs for that area (see Section 4.2).

4.1.2 Wastewater acts

Under the NWA, norms and standards have been set for the quality of treated wastewater or effluent prior to discharge into water sources. These consist of general and special standards and set limits for aspects such as pH, temperature, chemical oxygen demand (COD), suspended solids (SS), and metals. The test methods for determining these levels are also specified. Environmentally sensitive areas where special, more stringent standards apply are listed. Any industries or municipal or private wastewater treatment works discharging into rivers or the sea must comply with these limits. In turn, the entity operating a wastewater treatment works must set limits for industries discharging to the works, such that the DWS final discharge limits can be met.

4.2 BY-LAWS AT LOCAL GOVERNMENT LEVEL

The handling and management of industrial effluent discharge creates problems for local authorities. The discharge of large volumes of industrial effluents into municipal sewerage systems – in particular the discharge of effluents containing unwanted substances – can have a detrimental effect on the operation of the biological processes of the sewerage treatment works, resulting in non-compliance of the treated effluent with the NWA standards.

To prevent industries in a particular municipal area from discharging effluent streams that may have a negative impact on public water sources or the environment, local authorities set requirements that industries must comply with before they discharge into the municipal sewerage system. In accordance with these requirements, industries need to apply for a special permit to discharge effluent into the wastewater treatment works. The by-laws set limits for the quality of the effluent, as well as for the discharge of any specific undesirable substances; the special effluent permits indicate the maximum volume that can be discharged, along with any special measures relating to the quality of effluent for the specific industry. By virtue of these by-laws and permit systems, local municipalities have some control over the type and quantity of industrial effluent discharged into their sewerage treatment works.

The problem with the by-laws for industrial runoff is in their application – particularly the calculation of effluent charges for certain industries carrying high loadings and/or undesirable substances in the sewer discharge. The laws can vary significantly from one municipality to another, in terms of the method for calculation of effluent charges as well as the frequency of sampling and the limits placed on specific pollutants that may be discharged. These differences in by-laws and control measures not only lead to confusion among the regulatory authorities, but also among the industries they serve.

4.2.1 Industrial effluent tariffs

Industrial effluent tariffs vary significantly from one municipality to the next, depending on the cost-recovery systems of the municipalities, types of industries discharging into the municipal sewerage system, and the receiving wastewater treatment works.

Principles in respect of industrial effluent charges to recover costs

A rational system should be used to calculate tariffs. The system should ensure that the total annual cost for the operation of the sewerage system and the wastewater treatment plant is recovered.

The following are important principles relating to the preparation of industrial effluent charge calculations:

- The 'polluter pays' principle contained in the NWA should apply. Industries should pay for their portion of the transportation and treatment costs of effluent.
- All sewerage rates should be calculated according to the same rationale. Each local municipality should strive to formulate its tariff structure in such a way that there is neither a loss nor a profit made on the wastewater treatment system.
- As is the case for water and electricity tariffs, the main objectives of sewerage tariffs are firstly to recover the full costs of providing the service, and secondly to prevent unnecessary waste and pollution.
- The rate charged for an industry must apply to the proportional costs for transport and treatment of discharge from the relevant industry. These costs include interest amortisation on capital works.
- The costs for transporting the effluent should not be based on the geographical location (i.e. the same unit rates for transport should apply to all).

4.3 SUMMARY OF EFFLUENT QUALITY REQUIREMENTS RELEVANT TO THE FOOD AND VEGETABLE PROCESSING INDUSTRY

Table 4.1 shows the effluent quality requirements of selected municipalities with fruit and vegetable processing industries operating within their area of jurisdiction. For contextualisation, the table also shows effluent quality requirements for a number of other municipalities.

Table 4.1: Effluent standards of municipalities for some of the most commonly regulated water-quality parameters for effluent from fruit and vegetable processing industries

Local Authority/Country	pH	COD (mg/L)	Ortho-phosphate (mg/L as P)	TSS (mg/L)	EC (mS/m) or TDS (mg/L)	Sulphate (mg/L as SO_4)	Total Sugar and Starch (as Sucrose) (mg/L)	Chloride (mg/L as Cl)
Municipalities with fruit and vegetable processing industries								
Phalaborwa		5 000					1 500	
Buffalo City				1 500			1 000	
Ekurhuleni	6–10	5 000	50	1 000	500	1 800		100
Greater Tzaneen				2 000 (L) 1 000 (S)	TDS: 1 000 (L) 500 (S)		1 000 (L) 500 (S)	
Nelson Mandela Bay	6–12	10 000	-	1 000	500	1 500		1 000
Other South African municipalities								
City of Tshwane	6–10	5 000	10	2 000	300	1 800		100
City of Cape Town	5.5–12	5 000	25	1 000	500	1 500		1 500
Oudtshoorn	6.5–10	4 000	10	1 000	500	250		500
Mossel Bay	6–11	3 000	-	1 000	500	500		1 000
Global								
France*	6.5–8.5	2,000	-	600	-	-		-
Italy*	5.5–9.5	500	-	200	-	1 000		1 200
India*	5.5–9.0	-	-	100	-	1 000		-

L = large wastewater treatment works (> 25 ML/d)   S = small wastewater treatment works (< 25 ML/d)

* Buljan and Kral, 2011

4.4 INTERVENTIONS PROPOSED TO LOCAL AUTHORITIES BY STAKEHOLDERS IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

In a report by the Western Cape Government Department of Economic Development and Tourism (DEDAT) (see Section 5.3), a number of interventions were proposed by stakeholders in the fruit and vegetable processing industry – particularly measures or actions that they felt could and should be undertaken by authorities and practitioners in this industry sector to ensure reduced and/or more effective water usage (especially in conditions of water scarcity). The proposed interventions are listed and discussed in Section 5.3, but those for local authorities are summarised as the following:

- The development of new infrastructure to augment water supplies should timeously be made part of the public participation process to ensure inclusion in the Spatial Development Framework (SDF) of the local authority. Budgets can only be allocated to these projects once they are part of the SDF.
- A document should be developed to provide standards and guidance for borehole drilling, pump testing, the process for obtaining the required authorisation, and the monitoring requirements for after implementation.
- A similar document needs to be compiled to assist companies that want undertake desalination of seawater and the reuse of treated effluent.
- The income from water sales should be ringfenced and only used for operational costs relating to water supply, the refurbishment of water infrastructure, and the development of alternative water resources.
- Joint water augmentation schemes through partnerships between local authorities and businesses (PPPs) – such as the reuse of treated effluent – should be investigated and promoted. Businesses might be willing to contribute to the cost of these schemes to increase their water resilience.
- Improved water management by local authorities is required to ensure that high quality water is provided to the agri-processing sector. High water quality is non-negotiable, as hygienic conditions should always prevail during the agri-processing sequence and are a legal requirement.
- Improved maintenance of bulk water infrastructure by local authorities is required to reduce losses in water supply systems. This will also ensure that all possible winter runoff is captured in the storage dams and then made available to water users.
- Improved communication between local authorities and businesses about the water situation and water issues is required. Honesty and openness are required in these timeous communications. A structured approach to water restrictions in times of increasing water shortages should be followed. This should include the possibility of differential water pressure management being implemented by the local authority.

- Local authorities should be upfront in terms of water restrictions and increased water tariffs to allow businesses to plan accordingly. The high drought water tariffs severely impact the financial viability of the agri-processing sector and the tariffs should differentiate at town level to minimise the impact on the agri-processing sector.
- Staff of local authorities need to be trained to allow them to provide accurate information to water users on augmentation options, such as when groundwater is planned to be developed and the correct procedure to follow to obtain the required authorisations.
- Water restrictions implemented should be town specific, depending on the water resources available to individual towns and not a general restriction for the whole municipal area – which may include towns where ample water is available. Similarly, the drought-stepped tariffs should be town specific and aligned with the situation in that specific town. The DWS has a draft guidance document that can be used for this purpose.
- Some towns do not have a business chamber that can lead discussions with the local authority to put forward the problems experienced by businesses. Direct negotiations between the local authority and a single business normally result in a poor response in which the issues put on the table are not addressed. A collaborative approach should be encouraged.
- A water technology hub should be developed where businesses can access information on available technologies, barriers, possible financing options, incentives for participation, and cost-benefit analyses. The smaller agri-processing companies do not have dedicated knowledgeable staff that can guide them on technology availability/affordability to increase their water use efficiency.
- Examples of best management practices can also be shared through this water technology hub. To retain their competitive benefits, companies do not currently share this information. Costs of interventions are also not always disclosed.

CHAPTER 5: WATER USE AND MANAGEMENT

5.1 WATER USE IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

Meneses et al. (2017), in their review on water reconditioning and reuse in the food processing industry, note that:

> Knowledge about potential streams for water recovery and water quality requirements for different operations is limited and therefore does not allow for improvements in the most significant water consuming operations.

This lack of knowledge, in their view, is a significant hindrance to water conservation studies. Indeed, government-led surveys of best practices and water use, at least within the US context, appears to have tapered off after the 1960s and 1970s, to be replaced mainly with industry-generated reports and surveys (California League of Food Processors [CLFP], 2015). Since this data is not publicly available, even recent studies are forced to make use of metrics from earlier work (Bromley-Challenor et al., 2013; CLFP, 2015).

For the purposes of this literature review, it is also necessary to consider studies addressing food processing in general. This is done for two reasons: Firstly, many Best Management Practices (BMPs) are applicable for a wide variety of food processing subindustries. For example, IPPC (2006) stated that cleaning practices are not only applicable to dairy and edible oils, but also to fruit and vegetable products. Secondly, few studies focus specifically on fruit and vegetable processing. Instead, some products that form part of the subindustry are mentioned in the results, or as a subsection in the report/study (for example Bromley-Challenor et al., 2013; CLFP, 2015).

5.1.1 International studies investigating water use and best practices

Within the North American context, publicly available data on metrics related to water use were relatively abundant in the 1960s, but have become scarcer since the turn of the century (CLFP, 2015). The most recent metric data obtainable is that of the CLFP (2015), and prior to that a study by Mannapperuma (1993). The CLFP study is extremely useful in that it makes available a complete list of the most relevant literature (from 1977 to 1993) used as a baseline for comparison. A limiting factor to consider is that both these surveys focus on the US state of California and therefore may not be representative of the entire Northern America region. Amón et al. (2015) have investigated techniques used for water and energy recovery in Californian tomato paste processing, while Masanet et al. (2008) have written extensively on different energy and water saving techniques for the fruit and vegetable processing industry in general.

The European context is slightly more enlightening due to the European Union IPPC Directive, which introduced a framework requiring all member states to issue operating permits for industrial activities performing polluting activities (Klemeš and Perry, 2007). The permits must contain conditions that take into account the best available techniques (BAT) in terms of pollution control and aim to provide a high level of environmental protection (IPPC, 2006; Klemeš and Perry, 2007). The IPPC Directive collects BATs from member states and uses them to compile BAT reference documents (BREFs). The BREF on the Food, Drink and Milk Industry (promulgated in 2006) contains metric comparisons for a wide variety of fruit and vegetable products, as well as techniques that can increase water efficiency (IPPC, 2006). As at August 2018, only a working draft of an updated version was available (European IPPC Bureau, 2018) and therefore the 2006 version is still used to determine conditions relating to operating permits. Other studies to have emerged from the EU include one by Valta et al. (2017), who investigated typical wastewater sources and treatments within the Greek fruit and vegetable processing industry. Bromley-Challenor et al. (2013) have also reported on water use and water saving opportunities within the United Kingdom (UK) food and drink industry. Literature relating to studies from other regions include a report by the Australian Department of Agriculture (2007) relating to water saving and reuse opportunities in food processing. Meneses et al. (2017) have written a review on water reconditioning and reuse in the food processing industry at large.

Research Chapter 1 will focus on compiling and analysing all available metric data relating to water consumption in the international FVPI. Therefore the remainder of the literature review will focus only on available metrics in the South African context, as well as water saving techniques in general.

5.1.2 South African studies on water use and best practices in the fruit and vegetable processing industry

The availability of metric data pertaining to water use and information on best management practices (or even current practices) in South Africa is scant at best. The only publicly available data is that found in a national survey (NATSURV) similar to this one conducted by Binnie and Partners (1987) on behalf of the Water Research Commission (WRC). This report contains metric data for a wide variety of fruit and vegetable products, including the national average specific water intake (NASWI; Figure 5.1), effluent volumes, BOD, COD, and SS. The report also sets targets for the metrics, which may be achieved by applying the accompanying recommendations. The NATSURV was also accompanied by a guide for water use and effluent treatment (Binnie and Partners, 1987). The Guide to Water Use and Effluent Treatment (Binnie and Partners, 1987) makes specific mention of how one particular facility heavily distorted the NASWI for freezing of vegetables specifically. This was due to the facilitiy’s use of once-through cooling systems.

The NATSURV and accompanying guide by Binnie and Partners (1987) will be used as a comparative platform for determining industry progress in the subsequent research chapters.

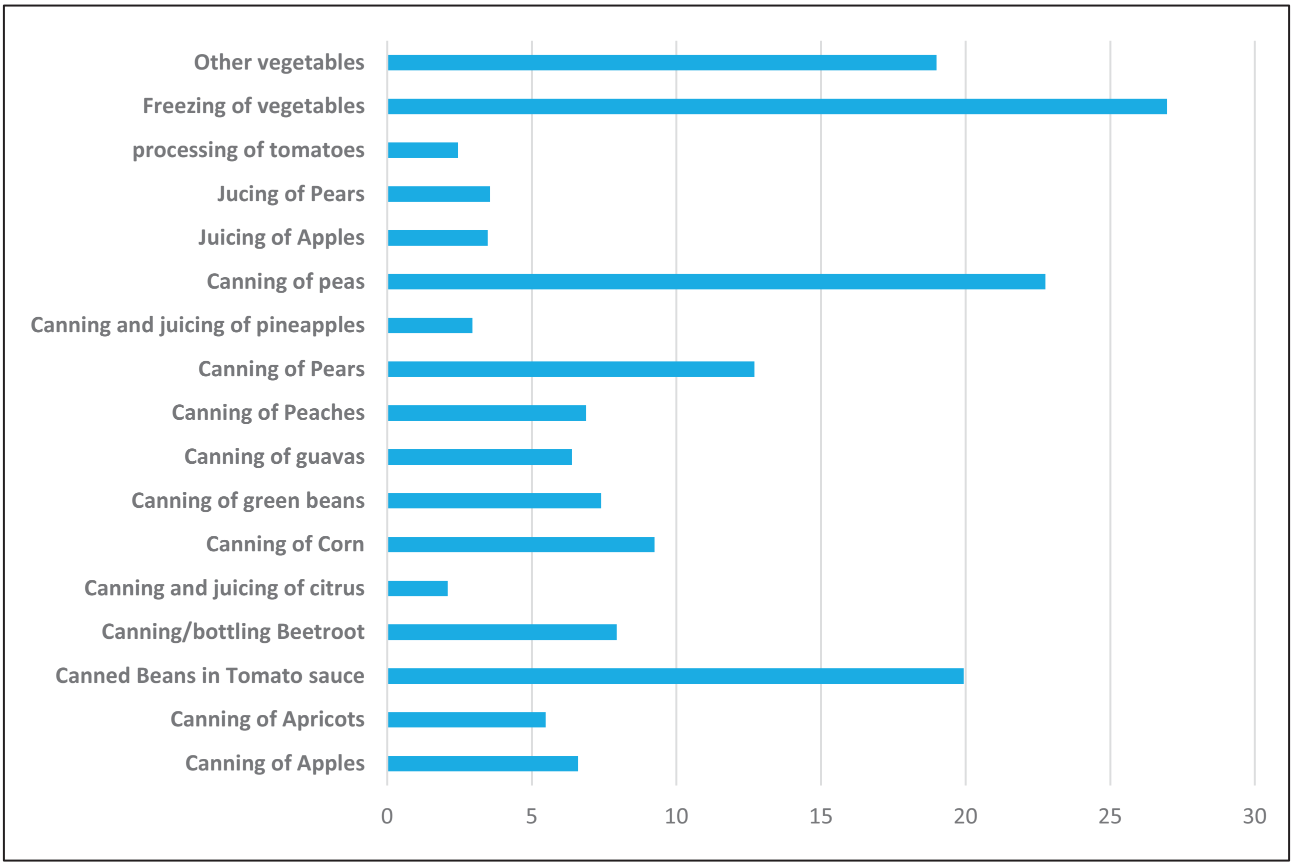

Figure 5.1: NASWI per product category (m^3 per ton of raw material) in 1987

(Binnie and Partners, 1987).

5.2 MODE OF INFORMATION AND DATA ACQUISITION

The two main objectives set by the project team in terms of data acquisition for this revised NATSURV were the following:

a. The creation of an up-to-date processing facilities database.

b. The establishment of preliminary contact with the relevant managerial personnel at each processing facility.

Goals (a) and (b) were both timeously achieved by taking the following steps:

1. Contact was made with the relevant industry bodies for the purpose of acquiring the lists of current members. The three main industry bodies are:
    - SAFVCA (South African Fruit & Vegetable Canners 'Association);
    - SAFJA (South African Fruit Juice Association); and

- DFTS (Dried Fruit Technical Services).

2. Members of each of these industry bodies were then telephonically contacted. The contact details provided by industry bodies were usually front-desk numbers, and therefore the main goal of these telephonic conversations was to achieve contact with (and obtain the email address of) the production manager at each facility. These individuals were selected because they were the most likely have the most intimate knowledge of the main water-using operations, as well as access to water management data.

3. Internet searches were conducted for factories/companies that did not belong to any of the industry bodies. Personnel at these factories were also telephonically contacted and contact established with the production managers (as in Step 2).

4. A database for verified processing facilities in South Africa was created using Microsoft Excel (the list of companies included in database is shown below) and the data graphically displayed using Tableau Professional 10.5.

The following should be noted:

The membership lists sent by industry bodies were mostly outdated. Many of the factories had become subsidiaries of larger corporates or simply no longer existed. A major difficulty experienced was establishing contact with any of the Tiger Brands Facilities. Still experiencing the aftermath of the Listeria outbreak, they were unwilling/unable to provide locations and/or contact details for their facilities. These difficulties can be resolved by establishing a central database for food processing facilities and keeping it updated. Greater transparency is also encouraged for food processing companies.

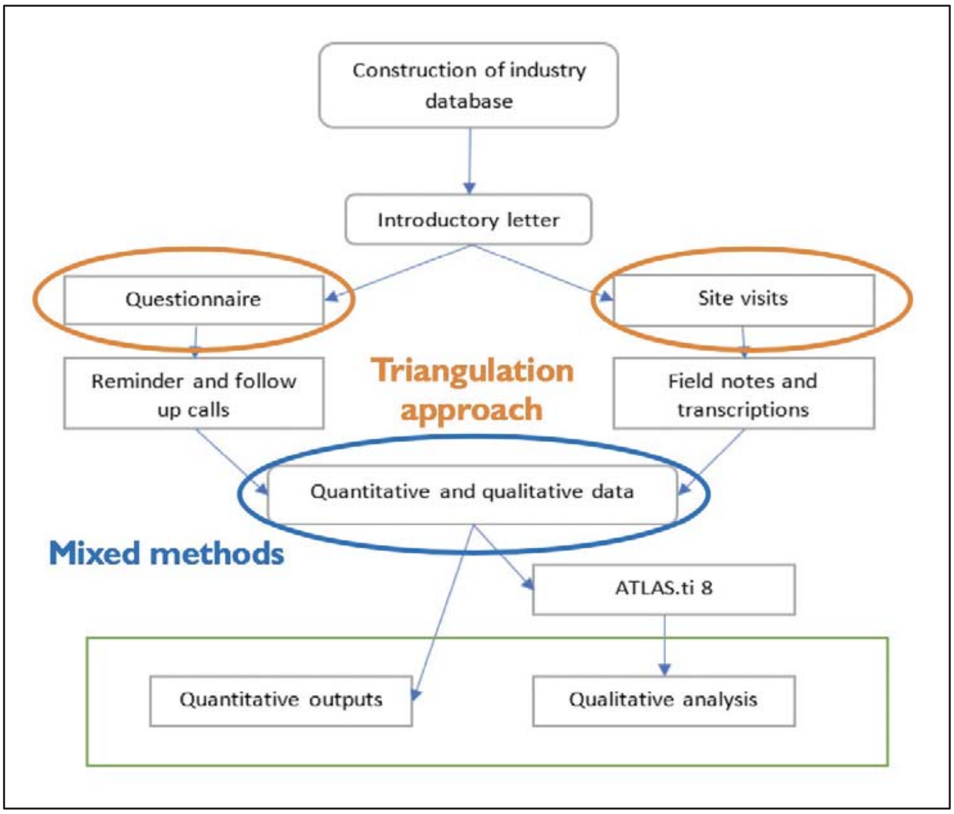

Figure 5.2: Flow diagram showing information gathering and analysis methods

5.3 WESTERN CAPE GOVERNMENT DEDAT SURVEY OF THE AGRO-PROCESSING INDUSTRY

A survey was conducted in 2018 by the Western Cape Government Department of Economic Development and Tourism (DEDAT) to provide a broad assessment of the water requirements of the agri-processing sector in the Western Cape (OABS, 2019). The study included obtaining typical water use per unit processed and risks that may result from insufficient quantities of water. The challenges in determining how the industry can increase its resilience to water shortages were also identified. The water-related risks, challenges, and impacts of the agri-processing sector were considered generally, while more detailed assessments were undertaken for the fruit and vegetables and dairy subsectors. A second aim of the survey was to develop a programme (along with its implementation plan) to increase the economic water resilience of agri-processors through focusing on short-, medium-, and long-term interventions to mitigate the impact of water risks. Another key aim of the project was to determine the volume of water currently used by the agri-processing sector and selected subsectors in the Western Cape and their projected future water needs per unit processed and total. This included the fruit and vegetable processing industry; the results and findings applicable to the NATSURV 14 (Edition 2) document are presented below.

5.3.1 Methodology

A questionnaire was developed to guide the interviews and to ensure consistency in the questions asked and the inputs obtained. The DEDAT and GreenCape gave comments and inputs into the questionnaire. The following information (method indicated in brackets) was typically requested or researched (OABS, 2019):

- Water-use benchmarking (desktop research and interviews)
- Impact of water restrictions (desktop research and interviews)
- Water quality (desktop research and interviews)
- Impacts of water-related issues on each business's operations (desktop research and interviews)
- Risk of water insecurity in the agri-processing sector (desktop research and interviews)
- Climate change projections (desktop research)
- Historical water use for processing one unit of a product (interviews)
- Current water-use efficiency achieved through water saving initiatives and improved opportunities for further water savings (interviews)
- Future water savings already being planned for (interviews)
- Technology/equipment options which will/can be used to increase water use efficiency (interviews)
- Estimated cost of implementing said technology (interviews)
- Projected future water requirements of agri-businesses (interviews).

Personal interviews were conducted with staff of selected representative organisations in the agri-processing sector and subsectors, using the questionnaire as the guide. The most appropriate representatives of the organisations were targeted for the interviews to ensure that the most accurate and available data was obtained. The data was treated according to each agri-processing business's preferences on confidentiality and privacy.

5.3.2 Industries visited and interviewed

The following fruit and vegetable processing industries were visited, and interviews were conducted using the methods specified above:

Langeberg and Ashton Foods (canning)	Lamberts Bay Foods (potato chips)
Ceres Fruit Processors	Elgin Fruit Juices
Rhodes Fruit Group	Tiger Brands
Pioneer Foods (Ceres Fruit Juices, Liqui Fruit)	Distell (winemaking, distilleries, and grape juice)
KWV	Robertson Wines
Brenn-O-Kem	SCP (an affiliate of AECI; fruit juice)

For the purpose of confidentiality, the names of the companies that participated are not stated in the discussion below of the obtained information. In analyzing the data, codes were used to identify agri-processing companies and to differentiate between products processed.

5.3.3 Results

Referenced water use per raw product processed

This study focused on direct water consumption in agri-processing facilities, i.e. water that is used within the factory. Indirect water consumption refers to water used outside the factory and forms part of the inputs supply chain.

Some examples of comparative direct water use ratios per product that were found by OABS (2019) include the following:

- Water consumption that occurs during the processes of canning, juicing, winemaking, brandy production, and fruit drying during fruit processing in South Africa (mainly in the Western Cape) ranges from 7 to 10.7 m^3/ton of raw produce (Khan et al., 2015).
- A data set acquired for a relatively large fruit juice processing plant shows that it uses on average 12.5 litres of water to produce 1 litre of fruit juice. The NATSURV 3 report (WRC, 2015) reports average water use of 1.6 litres per litre of fruit juice (2013 survey), compared to the 2.7 litres used shown in the NATSURV 1987 survey.
- The results of an analysis of some agri-processing industries in the Western Cape show that just over 3 000 m^3 of water is used per annum to process approximately 15 500 tons of olives used to produce 2.6 million litres of olive oil (DEA and DP, 2015). This equates to 1.15 litres of water per litre of olive oil produced.

A list of some water use product ratios is presented in Table 5.1. The OABS report (2019) cautions that some of the water-use benchmarks, such as for frozen vegetables, are questionable and require further investigation.

Reported water use per raw product processed during interviews

Table 5.2 shows water-use ratios for a number of products, as reported during interviews with a range of agri-processing industries in the Western Cape. The year 2015 depicts pre-drought conditions and 2018 depicts drought conditions. The results indicate that most of the industries have made remarkable progress in water-use efficiency (rows marked in green are processors that are on or below the benchmark). However, a comparison of the Western Cape agri-processing water use per unit production with the average of the benchmarks (see Table 5.1) indicates the following (OABS, 2019):

- Water use for juice and beverage production is above the benchmark (from international and national sources) average (not necessarily behind other industries).

- The average benchmark (in red) for potatoes seems inaccurate when related to the water use per kilogram of processed reported for Fruit and Veg 1 (potatoes).
- Without exception, all the industries improved their water use efficiency during the drought.

Table 5.2: Water use ratios for products reported during interviews compared to the average benchmark (OABS, 2019)

Industry	Production Volume (Tons/Annum)	Total Water Use per Annum (kL)	Litre/Kilogram Raw Material Processed	Benchmark (L/kg) Average
Fruit and Veg 1 – 2015 (Canning)	130 000		8.3	7.62
Fruit and Veg 1 – 2018 (Canning)	89 000		6.2	
Fruit and Veg 2 (Potatoes)	22 200	600 kL/d 132 000/a	5.94	27.5
Fruit and Veg 3 – 2015 (Juice)	173 300	452 600	2.61	1.875
Fruit and Veg 1 – 2018 (Beverages)		478 000	2.47	1.875
Fruit and Veg 1 – 2015 (beverages)	3 285	20 200	6.15	1.875
Fruit and Veg 1 – 2018 (beverages)		14 600	5.27	1.875

Table 5.1 Water use (in litres) per unit of raw material produced for fruit and vegetable processing (OABS, 2019)

Benchmarking Element	Min	Average	Max	Measuring Unit
Apples (Canned)	4.3	6.62	11.25	L/kg
Apples (Juiced)		1.84		L/kg
Apricots (Canned)	2.5	5.5	11.5	L/kg
Beans in Tomato Sauce (Canned)	20	20	70	L/kg
Beetroot (Bottling)	8	8	24.8	L/kg
Citrus (Canned and Juiced)	1.1	2.08	2.6	L/kg
Corn (Canned)	6	9.25	11	L/kg
Green Beans (Canned)		7.4		L/kg
Guavas (Canned)	4	6.4	7	L/kg
Peaches (Canned)	2.5	6.88	12	L/kg
Pears (Canned)	4.5	12.7	29	L/kg
Pears (Juiced)		1.91		L/kg
Peas (Canned)	19	22.8	25	L/kg
Pineapples (Canned)	2.1	2.94	4.55	L/kg
Strawberries (Canned)	6.8	17.8	21	L/kg
Tomatoes (Canned)	2	2.44	3	L/kg
Broccoli (Frozen)		25		L/kg
Cauliflower (Frozen)		25		L/kg
Carrots (Frozen)	6	8.1	26	L/kg
Corn (Frozen)		4.63		L/kg
Green Beans (Frozen)	10	27	15	L/kg
Peas (Frozen)		30		L/kg
Potatoes (Frozen)		27.5		L/kg
Other (Frozen)		19		L/kg
Other (Canning)		9		L/kg
Berries (Canning)	6.8	17	27.65	L/kg

5.3.4 Conclusions

Water usage

OABS (2019) reports that, in general, the ratios for water use per processed product also reported during interviews indicate that most of the industries made remarkable progress in reducing their water use per unit output (efficiency gains) during the drought compared to the pre-drought period (albeit with significant investments in water demand management technologies and practices). Some industries managed to reduce their water use by 20–25% (e.g. canned fruit and table olives), while others did not do so well (e.g. olive oil and dairy, with a 9% saving). Some industries are already optimally using water, such as the wine and juice industries – which are close to reaching the international benchmark standards (OABS, 2019).

Water risks and responses by agri-processors

Excerpts from the OABS report (2019) are provided below.

⇒ Water restrictions that were imposed on water use by the respective local authorities had a severe impact on agri-businesses. Additional capital expenditure was incurred for infrastructure such as storage facilities and equipment, boreholes, pumps, and pipes. Water conservation and demand management measures were put in place for efficient water use and implementing grey-water recovery systems. Water reuse systems were installed or being planned in several agri-processing industries.

⇒ Water tariffs were increased for industries during the restrictions, but not with the same harsh tariffs as for household water use, although the total water use requirements were high in some cases. Production costs generally increased. The cost could not be passed on to the consumer, which resulted in reduced profit margins and therefore reduced financial resilience to water restrictions (OABS, 2019).

⇒ Water quality was reported as vital both for processing and for addition to some products (e.g. beverages). Pre-filtration of municipal water with carbon filtration systems was required for some industries to ensure that they complied with food and health safety standards to remain internationally competitive (protecting their reputation) and to bolster resilience to lower water quality impacts.

⇒ Feedback from agri-processing industries shows a general agreement among stakeholders that planning must be done for water shortages during anticipated longer drought periods. Agri-processing industries have already implemented strict water conservation and demand management projects for efficient water use. Training of personnel and raising of awareness continue. Further savings from existing sources becomes more difficult, with large economic implications and lower production.

⇒ In most cases, companies managed to retain staff, although some had to reduce the number of working hours per day or number of shifts per week. Investments in alternative water supply resources at a high cost ensured that production could be maintained and staff employment retained.

⇒ Reduced water availability and security had a detrimental impact on the agri-businesses, resulting in decreases in both production volumes and resilience to bridge periods of lower production in the primary sector.

⇒ Loadshedding of electricity had a significant impact on the agri-processing sector as it disrupts the processing of products and in many cases results in damaged/spoilt products that need to be dumped due to either poor quality or hygiene risks. In most facilities, the equipment needs to be cleaned after a loadshedding stoppage, resulting in additional washing water used and increase production downtime. This downtime can necessitate staff working overtime to process products to stay withing processing-related time limits.

Identified barriers to water resilience

Although the emphasis of OABS report (2019) was on the improvement of agri-processing economic water resilience, it is important to understand that water resilience is only one element of agricultural value chain resilience. The following barriers to increasing water resilience were identified:

- A lack of proper maintenance and refurbishment of infrastructure. Income derived from water sales/tariffs is not ringfenced for this purpose. A lack of technical expertise and knowledge in some local municipalities results in poor maintenance and management of water infrastructure, and can lead to excessive water losses and water use that is unaccounted for.
- The quality of the water provided to users can sometimes be below acceptable standards during low water levels or breakages in distribution systems. This can seriously impact the agri-processing sector, which relies on properly treated water to maintain the necessary hygiene standards.
- The impact of very high water tariffs as a form of water restrictions on the financial security of the agri-processing sector is significant. Interviewees asked that this be brought to the attention of local authorities. These companies buy large volumes of water from their water service providers (municipalities), contribute towards the income of the local authority through the rates and taxes paid for water and other municipal services, and provide job opportunities to many people in towns where processing facilities are situated. The financial security of the agri-processing companies is severely negatively affected by the high water tariffs, which can negatively impact the local authority if more industries secure their own water sources and go off-grid.
- Loadshedding of electricity is a key constraint and impacts the competitiveness of agri-businesses since it has significant water use efficiency and cost implications for some agri-processors.

Interventions proposed by stakeholders (as per excerpt from OABS, 2019)

A number of interventions proposed in the report by stakeholders in the fruit and vegetable processing industry are provided verbatim below. Those that relate to actions required by local authorities are summarised in Section 4.

- Water conservation and water demand management (WCWDM) initiatives are always the first steps to be taken to reduce water use, because these are most often the more affordable and cost-effective efficiency options available. These include:
  - training/creating awareness of staff;
  - identifying and reducing losses and water wastage; and
  - implementing innovations proposed by staff.
- Public perceptions on the re-use of waste water within the food industry should be changed through education and capacity building to create an understanding of the safety of reuse systems.
- Water augmentation options should also include desalination of sea water, the development of groundwater resources, and the reuse of treated effluent to create increased resilience. Current water

supply options are all reliant on surface water (rainfall) and this results in an unacceptable level of water undersupply risk to the agri-processing sector.

- Improved maintenance of bulk water infrastructure by local authorities is required to reduce losses in water supply systems. This will also ensure that all possible winter runoff is captured in the storage dams and then made available to water users.
- Water savings incentives/financial support from local authorities/government are required to support agri-businesses to embark on water saving initiatives. The very low profit margins of the dairy processors limit their ability to embark on these initiatives without support. The reduced water demand resulting from these initiatives can be regarded as water augmentation options for the local authorities.
- Agri-processing companies can sponsor water efficient appliances/technologies for their staff to implement at their houses. Some companies support their staff by providing information but not appliances.
- Metering of water right through all the agri-processing phases should be standard practice as it can indicate critical areas where water savings can be achieved. This can include real-time monitoring. Water metering information can be included in the technology hub.
- Water audits can assist to increase their water use efficiency. The Centre, South(NCPC-SA) continues with the drive to raise awareness in industry and government about the importance of water management. Through their Industrial Water Efficiency (IWE) Project, companies can apply for free water assessments and assistance with implementing water efficiency in their plants (Engineering News, 2018).

5.4 WATER USE IN THE INDUSTRIES THAT WERE VISITED (NATSURV 14)

Industrial unit 3013.1 is located in Limpopo and is involved in the juicing of citrus fruits, with grapefruit and oranges being the main varieties processed. The only output is juice concentrate, which is mainly exported. The permanent staff contingent currently comprises 102 individuals, with seasonal staff totalling 84 people (February to middle October). Water is drawn from a local dam, although the recent drought encouraged the facility to sink a borehole on the premises, making groundwater an alternative water source. Water is used primarily for raw material washing, cooling towers for the freezers, and for pasteurisation. The water used in oil extraction processes was also mentioned. Water saving techniques exhibited by the facility include two recycling strategies: the reuse of evaporator water for cleaning the facility and equipment, as well as the collection of the defrost water from the freezers (which is in turn used to replenish the cooling tower water levels). High-pressure hosepipes were used for cleaning, although it was noted that some of the hosepipes used at the facility were not adequate (Figure 5.3). Dedicated leak repair efforts were also mentioned as a water loss mitigation technique.

Figure 5.3: Use of normal hosepipes still apparent at Facility 3013.1.

Industrial unit 3013.2 is involved in the processing of fruits, with tropical varieties as the main inputs. Three different on-site facilities manufacture juice concentrates/blends/purees, fruit cubes, individually quick-frozen (IQF) fruit pieces, and canned products. The peak season for juicing runs from November to January the following year, while the IQF and canned products are produced annually from March to early July, when grapefruit is in season. Municipal water is used, as well as groundwater from a borehole on site, which is stored in a small reservoir. The water is then treated before use in the factory. The physiochemical properties of the incoming water are tested every morning by laboratory staff. Within the IQF and canned products facility, the washing of raw materials used the most water, with floor cleaning (a near-continuous operation to prevent slipping) following suit. The juicing and sweets facilities both experience the cleaning operations to be the main users of water. Active water use minimisation techniques include the reuse of water used in IQF washing operations (water used in first and second rinses is chlorinated, then mixed with fresh potable water to be used again in the same operations) and the recirculation of water used to operate the conveyor bringing washed fruit into the IQF facility.

Industrial unit 3103.3 is a relatively small facility (in the Cederberg region) involved in the bottling of jams and other preserves – mainly for the domestic market. The raw materials are mostly deciduous fruits, including apricots, blueberries, apples, and pears. The total workforce comprises 17 permanent staff and six seasonal workers. Fresh water is supplied by a borehole, with the water itself being treated by a filter, brominator, and UV light system before use in the factory. Water was used mainly for pasteurising and preservation operations. Water minimisation techniques used at the facility are largely in response to the severe drought experienced in the Western Cape and consist of the following measures:

- Reusing of the pasteurised water
- Reduction in amount of water used for raw material washing (from 200 litres per day to 60 litres per day) as well as for cooking

- Reducing the number of times work outfits were washed (from three times per week to once per week)

Industrial unit 3013.4 is a potato processing facility located on the West Coast of South Africa. Other vegetables are used in secondary or tertiary processes, but these are usually bought in a pre-processed state. Ninety tons of potatoes are processed daily, for four days per week and year-round (although operations are halted during the December holiday period). Production is geared mainly towards the local market, although limited exports do occur to Namibia, Botswana, and Zambia. The facility uses a combination of seawater (used for initial washing and transport), borehole water (used for cleaning and secondary washing of potatoes), and municipal water (used for direct contact after peeling). Although the SWI for the facility is shown to be 6,2 m^3/ton, it must be taken into consideration that the volume of seawater and borehole water used in the process raises the actual SWI to 10 m^3/ton. The main uses of water were facility cleaning and as process water (more specifically for peeling and blanching operations), while freezer defrosting was another water-intensive operation. Active water-saving measures implemented by 3013.4 include the following:

- The installation of 10 electronic flow meters to assist in identifying water-saving opportunities
- Replacing old/incorrectly sized nozzles in the peel remover
- Automatic switches to stop the water flow once machinery is switched off
- Triggers on the hosepipes that eliminate wastage during cleaning operations

Industrial unit 3013.5 is a vegetable processing facility located in Limpopo. Four processing lines are active at the facility that process canned tomatoes, tomato puree, gherkins, and atchar (mango and vegetable varieties), respectively. Production is geared towards the local market, although cherry peppers are exported in very small quantities. The workforce comprises 146 permanent staff, with a seasonal staff contingent of between 300 and 500 at any given time. Boreholes supply the 80 000 to 160 000 litres of water required daily, with water used mainly for the washing of raw materials and cleaning operations. Active water-saving measures include the use of triggers on hosepipes, staff training, and the installation of water-dispensing points (accompanied by dispensing units for cleaning chemicals). Water from the pasteurisers and double-jacketed vessels goes through a condensate return to be reheated by the boiler (a form of regeneration reuse).

Industrial unit 3103.6 is a manufacturer of frozen vegetable products located in southern Gauteng. The facility provides employment to 426 permanent staff, with seasonal workers averaging 100 per 12-hour shift. The annual water use in the facility is 188 976 m^3 per annum, which is apportioned as follows:

- 1 089 m^3 for employee use
- 41 525 m^3 for cooling tower evaporation
- 33 975 m^3 for boiler operation
- 112 387 m^3 for other plant requirements (facility cleaning, material washing, and other purposes)

Water is used mainly for material washing and facility cleaning operations. Active water-saving measures include design-based optimisation (the only facility to have employed this), the recirculation of water in the slither remover, dedicated maintenance, water-wise cleaning (nozzles on hosepipes), and staff training.

Industrial unit 3103.7 is located in Limpopo and is involved in the production of bottled piquanté peppers, as well as other value-added vegetable products, including atchar, salsas, pickles, and sauces. Production occurs year-round, with a peak between January and June (due to the piquanté season). Of the total production, 80% of the output is exported, with Europe and North America being the main export destinations. The facility has a workforce of 230 permanent staff, with a day and night shift of seasonal workers making up approximately 2 500 individuals. Fresh water is supplied by the municipality, with the facility's daily water requirements being approximately 300 m^3. Active water-saving measures found in 3103.7 included the reuse of wash water (replaced once per day) and pasteuriser water (replaced once every two weeks). They also include water-awareness training for staff and the use of water-wise cleaning techniques (dry cleaning of certain areas and nozzles on hosepipes). A weekly leak check of the entire facility is also conducted.

Industrial unit 3103.8 is located in the Western Cape and comprises two separate facilities (eastern and western plants). The eastern plant is involved in the canning of deciduous fruits, while the western plant cans vegetables. The two sites have a combined permanent workforce of 500 and 4 500 seasonal employees. One third of the water requirement is used as raw ingredient, and two thirds of it is allocated to facility cleaning and material washing. Reduced water use has been a key focus at the facility since 2016, with the intervention being triggered by the looming drought. Interventions included the following:

- The installation of central shut-off valves – once work in a specific part of the plant is completed, water for the entire section is isolated.
- Water-efficient urinals
- Use of mountain/stream water instead of municipal water
- Closed system for water pumps
- Pressure reduction at handwashing stations
- More efficient lye-peeling heat exchangers

The above achieved a drastic reduction in water consumption, as shown in Figure 5.8. From 2016, the above water-saving strategies have resulted in a 54% reduction over two years (From 1 014 668 kL used in 2016 to 465 458 kL in 2018).

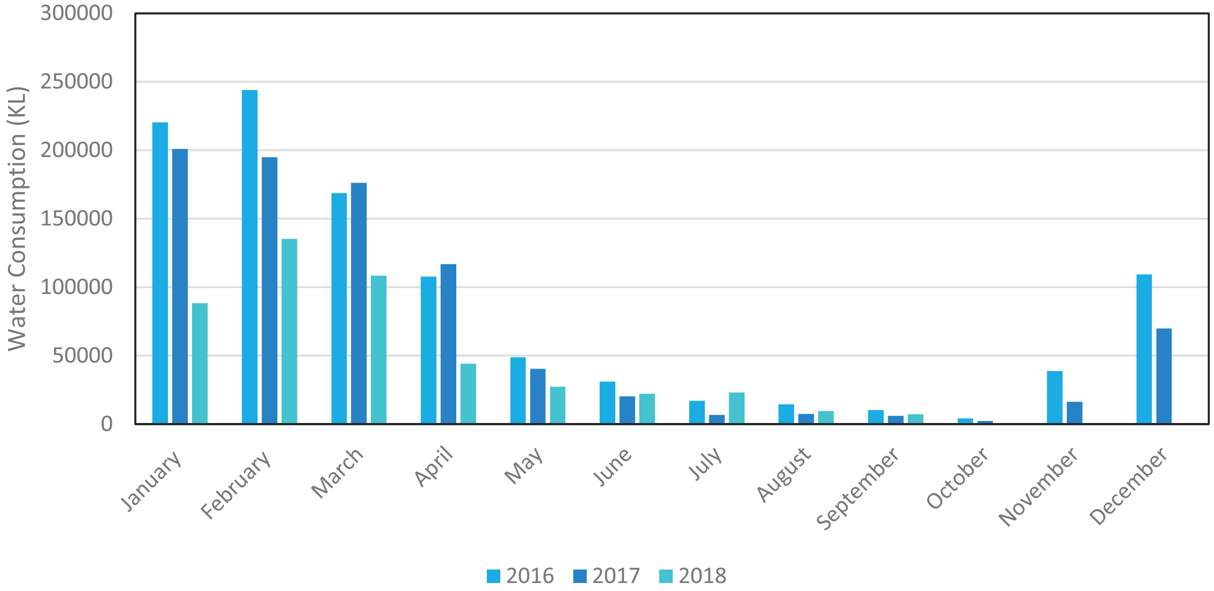

Figure 5.4: Water consumption at industrial unit 3013.8 from 2016 to 2018

Figure 5.9 shows the annual production (in tons) in relation to the water consumption (in kilolitres) at facility 3013.8. The highly water-dependent nature of production, as well as the seasonality of production, becomes very apparent.

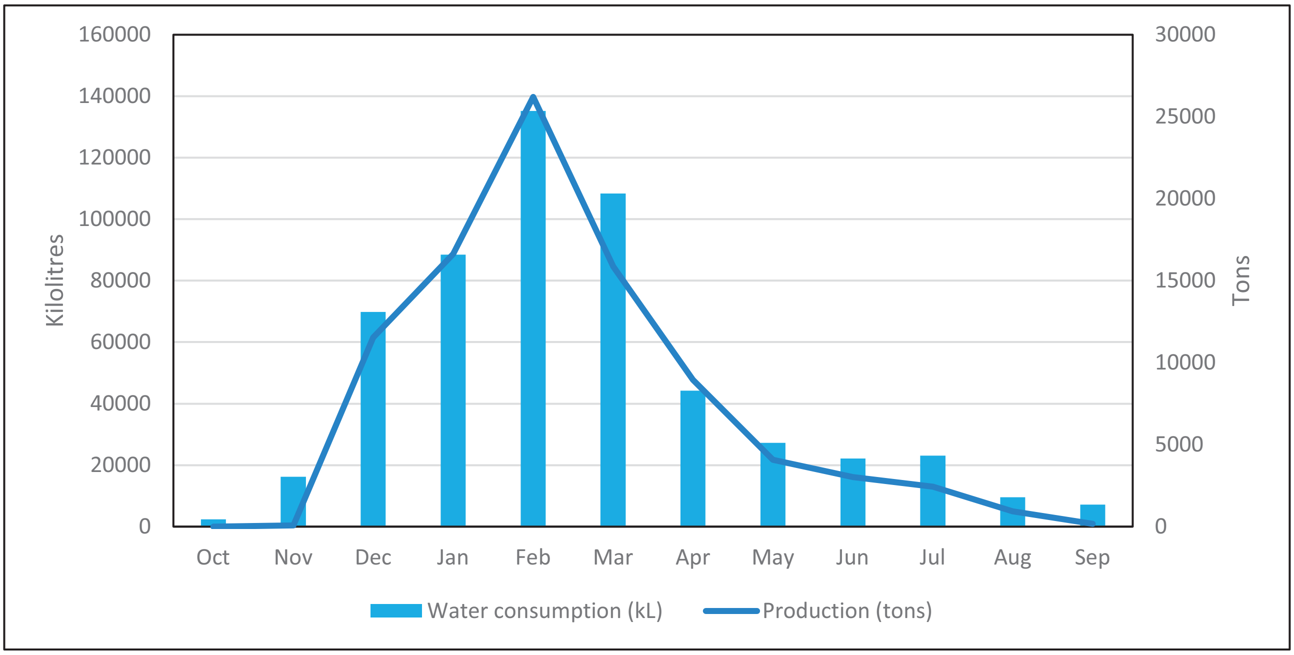

Figure 5.5: Annual water consumption and production at industrial unit 3013.8

Industrial unit 3013.9 is a dried fruit producer located in the Western Cape. The company employs 130 permanent staff, with the year-round supply of raw inputs (dried tree fruit from a variety of sources) ensuring no seasonal work. The company contributed approximately 1 000 tons of dried fruit per annum to the national dried tree fruit production total of 6 181 tons in 2017 (of which, industrial unit 3013.8 represents approximately 16%). The daily water requirements of 60 m^3 are met by a 60 m^3/hour borehole, and water is treated for high iron and manganese content before use in the plant. Water is used mainly for the washing of raw materials (Figure 5.10), followed by the cleaning of equipment. Active water-saving measures include timely maintenance and leak repairs, water-wise cleaning, and staff training. Replacing the worn-out nozzles in the initial fruit cleaning operation (Figure 5.10) reduced the water requirements of the equipment by approximately 75%.

Figure 5.6: Industrial raw material washing at industrial unit 3013.9

Industrial unit 3013.10 is located in the coastal region of the Eastern Cape and is involved primarily with the freezing of fruit products for niche markets abroad. Limited piquanté pepper canning also takes place on the premises. The company provides employment to 500 permanent staff, with seasonal employment raising this figure to 1 500 during peak periods (this occurs during the citrus season). Seven thousand tons of raw fruit is processed annually. The summer months (January to April) involve mainly the processing of deciduous fruit, while citrus is the main commodity processed during the winter months. Industrial unit 3013.10 is also involved in sorbet production, with fruit juice ingredients purchased from a variety of suppliers. Production is determined in units, with 15 million units (of approximately 100 grams each) being produced in 2018. The facility uses between 6 000 and 13 000 kilolitres of fresh water per month, with the water itself being provided by the Fish River Transfer System (ensuring a constant supply even during the most intense periods of drought). Incoming water quality is considered very important, with special emphasis being placed on chlorine limits and microbial loadings (UV filters are used to treat the incoming water). No data on water use within specific operations was available, although the main water-using activities were reported to be cleaning and washing. No data on specific water intakes for various products were available, either. The company has admitted that water minimisation is currently not a focus due to the constant supply provided by the Fish River Transfer System, as well as a focus on reducing the high energy requirements of the processes (approximately 1 200 kWh per month).

Industrial unit 3013.11 is an apple juicing facility located in the Southern Cape. The facility employs 100 permanent staff and does not rely on seasonal labour due to the highly mechanised process involved. Production runs from January to July, with a variety of cultivars being juiced. Total raw material consumption at the facility totals approximately 65 000 tons, which is used to produce approximately eight million litres of concentrate. By improving its production process, the facility was able to lower its water consumption of 300 000 m^3 (2018) to 200 000 m^3 (2019) – which is now also supplied by groundwater instead of municipal water. This changed due to an increase in the unit cost of water from R11/kL to R56/kL. The incoming water is treated for iron and *E. coli* and the water is primarily used for material washing and facility cleaning.

The facility is fortunate that for most of the season it is self-sufficient in terms of process water, with the condensate being reused for most of the processing requirements. Water minimisation was indicated as a focus area, evidenced by the planned installation of a UV filtration system in the initial washing area. By treating the washing water with the UV system, it is hoped that longer periods between wash water changeover can be achieved. A major advantage of the concentration process is the ability to collect and reuse the condensate as process water. Timely maintenance of leaks is also practiced, as is the separation of cleaning chemicals from wastewater for reuse.

As stated above, the facility made various changes to their production process. Two of their main focuses were reducing its water consumption and improving its water recovery processes. The facility no longer uses any cooling systems as they are too water intensive, and the activated carbon for filtering its juice has been replaced by an absorber. They are now able to achieve 80% condensate recovery. The facility further reports that all process water is recovered and that they experience minimal water losses. The effluent is subjected to a 10 000 L/h caustic recovery system, which could be improved to 20 000 L/h. The implementation of the caustic recovery system has resulted in a 50% reduction in water use. The caustic that is recovered is reused in the production process.

Industrial unit 3013.12 was involved in pineapple canning up until 2007/2008. Due to the unprofitable nature of canning, the decision was made to retrofit the factory, turning it into a juicing operation. Today, the factory is only involved in the production of pineapple concentrate, with small volumes of pure, fresh juice being produced. The company provides employment to approximately 120 staff (when the canning line was still in operation, this figure was 1 000). In 2018, industrial unit 3013.11 processed approximately 81 000 tons of raw fruit, with production in 2019 expected to increase to 87 000 tons. Processing occurs from late February until December because pineapples are potentially available year-round. Most of the production (85%) is exported, with the main destinations being Europe, Russia, and South America. Water minimisation has been named a focus area for the facility. They have recently eliminated their 'dumper baths' and now dump the fruit directly onto conveyor belts (Figure 5.11), where initial rinsing takes place. This measure has reduced water consumption by approximately 20%, with estimated annual savings of ZAR 1 million. In addition to this, the facility also reuses condensate from the evaporation process for the cleaning of floors and stainless-steel surfaces (the lower pH of the condensate restricts its use for other surfaces). The facility also uses clean-in-place (CIP) in certain equipment (such as the concentrate holding tanks).

Figure 5.7: Facility 3013.12 removed the 'dumper baths' and now loads fruit directly onto conveyer belts

Industrial unit 3013.13 is located in the Eastern Cape Province and is involved in the canning and bottling of various members of the *Capsicum* (pepper) family. Typical products include the red cherry pepper, sweetheart pepper, and jalapeño. Three thousand tons of packed product is produced from December until the end of March of the following year and is mainly exported. Industrial unit 3013.12 has faced a uniquely challenging situation in the past two production seasons, in that the local municipality was unable to meet the water requirements of the facility (due to drought pressure and reported mismanagement). In response to this, the facility had to resort to trucking in the 148 m^3 of water required daily from a nearby borehole. Active water-saving measures in the facility include the following:

- Use of a sanitisation protocol (sanitiser and water applied using compressed air) instead of traditional cleaning with a hosepipe
- Use of broom and squeegee for basic cleaning
- Reduced change-over of washing tank water
- Staff training

Industrial unit 3013.14 is located in the Eastern Cape and is involved in the juicing of citrus for concentrate production. Ninety thousand tons of citrus is juiced annually from March until the end of October, with a facility shutdown and capital projects phase occurring from November to February the following year. The facility employs 160 seasonal staff with a permanent contingent of 37 individuals. The facility obtains all its water from a local irrigation canal system. Water was used mainly in evaporators and boilers. Water-saving measures implemented at the facility include the following:

- Redesign of piping for improved water efficiency
- Reuse of condensate water and planned reuse of vacuum pump water
- Monitoring of water consumption
- Recirculation of boiler water
- Improving the energy efficiency of the steam-based systems (redesign of boiler layout and insulation of steam piping)
- Water-wise cleaning (high-pressure cleaning)

Industrial unit 3013.15 is a juicing and packaging facility located in the Boland region of the Western Cape. The production period runs from October through to April the following year. The facility handles seven million kilograms of concentrate and pressed juice per year. Their annual water consumption requirement of 2 mL is supplied by the municipal system, two boreholes, and a water recovery system. The incoming water is passed through a sand filter, after which chlorine is added. The incoming water is also subjected to UV treatment. Water is used mainly for the washing of equipment followed by production processes.

5.5 WATER USE AND WATER MANAGEMENT AT VISITED INDUSTRIES

Table 5.1 shows the annual fresh water consumption of the industries in 2018. The calculated SWI values of the 10 selected fruit and vegetable processing industries that were visited are presented in Table 5.2 and the use per process (where this information is available) for different types of fruit and vegetable processing industries in Table 5.3.

Table 5.1: Production and water consumption data from survey responses

Industrial unit	Production	Production season	Source of fresh water	Annual freshwater consumption (m^3)
3013.1	15 000 tons of grapes to produce 12 000 m^3 of juice annually	January to December	Municipal	3 000
3013.2	60 000 tons of apples and 10 000 tons of pears annually to produce fruit juice	January to May	River/dam	277 000
3013.3	10 000 tons of grapes for raisin production	February to November	Municipal	13 173
3013.4	6 000 tons of grapes for raisin production	February to September	Municipal river/dam	No records kept
3013.5	50 466 tons of citrus and 4 461 tons of guava annually for juicing	February to September	Municipal	123 870

Table 5.2: Water-saving measures from survey responses

Industrial unit	Prioritisation of water minimisation (scale of 1 to 5)	Water use targets in place (yes/no)	Water-saving measures in use	Measures implemented in response to recent drought (yes/no)
3013.1	3	No	Process control and monitoring Dedicated maintenance Water-wise cleaning (high-pressure spray units)	No
3013.2	5	No	Water reuse and recycling Process control and monitoring Avoidance of once-through use Improved energy efficiency in steam-based processes Water-awareness training for staff	No
3013.3	5	No	Dedicated maintenance	No
3013.4	3	No	Water-awareness training for staff Dedicated maintenance	No
3013.5	5	Yes	Water reuse and recycling Improved energy efficiency in steam-based processes Dedicated maintenance Water-awareness training for staff	Yes

Table 5.3: Facility descriptions (1)

Industry identification (code number)	Industrial unit 3013.1	Industrial unit 3103.2	Industrial unit 3013.3
Type of processing (canning, juicing, etc.)	Juicing	Juicing, canning, freezing	Canning
Types of fruit or vegetables processed	Citrus	Tropical fruits	Deciduous fruits
Market	Export	Export	Local
Production season (months)	February to October	November to Jannuary; March to July	January to December
Reported main water-using processes	Cooling towers Raw material washing Pasteurisers Oil extraction	Washing of raw materials Cleaning	Pasteurisation Cooking operations
Water intake			
Water source (municipal, borehole, etc.)	Dam, borehole	Municipal, borehole	Borehole
Water intake volumes	Not provided	Not provided	1.58 m^3 p/d
Specific water intake (SWI) **[Volume of water per kg or ton of product processed]**	Not provided	Not provided	Not provided
Wastewater volume	Unknown	Unknown	500 m^3 p/a
Wastewater quality	Unknown	Unknown	COD: 23 350 mg/L TSS: 78 mg/L pH: 6.1
Water conservation measures	Reuse of evaporator water for cleaning. High pressure hoses Dedicated leak repair.	Reuse of washing water in freezing operations. Recirculation of water on conveying systems for fruit.	Reuse of pasteuriser water. Reduction in water used for material washing.

Table 5.4: Facility descriptions (2)

Industry identification (code number)	Industrial unit 3013.4	Industrial unit 3103.5	Industrial unit 3103.6
Type of processing (canning, juicing, etc.)	Freezing	Canning	Freezing
Types of fruit or vegetables processed	Potatoes	Tomatoes, gherkins, mango, cherry peppers, other	Various vegetables
Market	Local	Local	Local
Production season (months)	January to November	January to November	January to December
Reported main water-using processes	Facility cleaning Peeling and blanching Freezer defrosting	Washing of raw materials Cleaning operations	Facility cleaning Material washing
Water intake			
Water source (municipal, borehole, etc.)	Seawater, municipal, borehole	Boreholes	Municipal
Water intake volumes (m^3)	143 018 p/a	188 796 p/a	188 976 p/a
Specific water intake (SWI) **[Volume of water per kg or ton of product processed]**	6.2	1.6	3.3
Wastewater volume (m^3)	177 710 p/a	10 000 tons per year (figure provided)	381 779
Wastewater quality	COD: 4 155–6 350 mg/L TSS: 533–20 168 mg/L pH: 4.7–6.2	COD: Not provided TSS: 1 740 mg/L pH: 7.0	COD: 410–5,810 mg/L TSS: 330–1,844 mg/L pH: 4.4–8
Water conservation measures	Installation of 10 electronic flow meters. Replacing old nozzles in peel remover. Automatic stop switches for water flow in machinery. Triggers on hosepipes.	Triggers on hosepipes. Staff training. Installation of water dispensing points. Reuse of water in pasteuriser and double-jacketed vessels.	Redesign of internal piping. Recirculation of water in slither remover. Dedicated maintenance and water-wise cleaning (nozzles on hosepipes).

Table 5.5: Facility descriptions (3)

Industry identification (code number)	Industrial unit 3013.7	Industrial unit 3103.8	Industrial unit 3013.9
Type of processing (canning, juicing, etc.)	Canning/bottling	Canning	Drying
Types of fruit or vegetables processed	Piquanté peppers, other	Deciduous fruits and vegetables	Deciduous fruits
Market	Export	Local	Local
Production season (months)	January to December	December to July	January to December
Reported main water-using processes	Washing Blanching Pasteurisation	Material washing Facility cleaning	Equipment cleaning Material washing
Water intake			
Water source (municipal, borehole, etc.)	Municipal	River, municipal	Borehole
Water intake volumes (m^3)	78 545 p/a	553 824 p/a	60 p/d
Specific water intake (SWI) [m^3 of water/ton product]	19.2	6.16	15
Wastewater volume (m^3)	800 p/a*	332 294 p/a	Not provided
Wastewater quality	COD: 3 429–10 059 mg/L TSS: 813–1 500 mg/L pH: 4.1	COD: 1 596 TSS: Not provided pH: 5.9	COD: < 100 mg/L TSS: Not provided pH: Not provided
Water conservation measures	Reuse of wash water and pasteuriser water. Staff training. Water-wise cleaning (dry cleaning in certain areas and nozzles on hosepipes). Weakly leak check.	Central shut-off valves installed. Water efficient urinals. Use of mountain/stream water instead of municipal. Closed system for water pumps. Pressure reduction at handwashing stations. More efficient lye-peeling heat exchangers.	Timely maintenance and leak repair. Water-wise cleaning. Staff training. Replacing the worn-out nozzles in the initial fruit cleaning operation.

* Facility 3013.12 claims that the very low effluent volume (compared to annual water consumption of 78 545 m^3) is due to evaporation-related losses during the processes. However, this seems unlikely, and leads to the suspicion that the water meter readings may be inaccurate.

Table 5.6: Facility descriptions (4)

Industry identification (code number)	Industrial unit 3013.10	Industrial unit 3103.11	Industrial unit 3013.12
Type of processing (canning, juicing, etc.)	Canning, freezing	Juicing	Juicing
Types of fruit or vegetables processed	Piquanté peppers, deciduous fruits	Apples	Pineapple
Market	Export	Export	Export
Production season (months)	January to December	January to July	January to December
Reported main water-using processes	Cleaning operations Raw material washing	Material washing Facility cleaning	Equipment cleaning Material washing
Water intake			
Water source (municipal, borehole, etc.)	River	Municipal	Municipal
Water intake volumes (m^3)	6 000–13 000 p/m	300 000 p/a	101 164 p/a
Specific water intake (SWI) [m^3 of water/ton product]	19,2	4,9	10,15
Wastewater volume (m^3)	4 800–10 400 p/m*	21 900 p/a	Not provided
Wastewater quality	Not provided	COD: 6 000–8 000 mg/L TSS: Not provided pH: 6,31	Not Provided
Water conservation measures	Water saving not considered a priority – no active measures implemented.	Condensate reuse. Planned installation of UV filtration system in initial washing area for extended time between water change over. Leak repair. Separation of cleaning chemicals from wastewater for reuse.	Replacing of 'dumper baths' in favour of dumping the fruit directly onto conveyor belts. Reuse of condensate for cleaning of floors and stainless steel surfaces.

*Facility 3013.15 estimates that the effluent volume totals 80% of the incoming water supply (therefore 80% of the water intake volume).

Table 5.7: Facility descriptions (5)

Industry identification (code number)	Industrial unit 3013.13	Industrial unit 3103.14
Type of processing (canning, juicing, etc.)	Canning/bottling	Juicing
Types of fruit or vegetables processed	Peppers (various), vegetables	Citrus fruits
Market	Export	Export
Production season (months)	December to March	March to October
Reported main water-using processes	Raw material washing	Evaporators Boilers
Water intake		
Water source (municipal, borehole, etc.)	Borehole	River
Water intake volumes (m^3)	17 700 p/a	90 918 p/a
Specific water intake (SWI) [m^3 of water/ton product]	5.9	Not provided
Wastewater volume (m^3)	10 380 p/a	100 000 p/a
Wastewater quality	Not measured	Not provided
Water conservation measures	Use of a sanitisation protocol (sanitiser and water applied using compressed air). Broom and squeegee for basic cleaning. Reduced change-over of washing tank water. Staff training. Installation of toilets with improved water efficiency.	Redesigning of piping for improved water efficiency. Reuse of condensate water. Planned reuse of vacuum pump water. Redesign of boiler layout and insulation of steam piping. Water-wise cleaning (high pressure cleaning). Recirculation of boiler water.

Table 5.8: Water-efficiency indicators

Facility	Main products	Fresh water consumption (m^3)	SWI (m^3/ton product)	SWI (m^3/ton product) according to literature
3013.6	Citrus concentrate	Not provided	Not provided	Fruit juice (EU): 6.5 Fruit juice (UK): 3.5
3013.7	Frozen fruit pieces Citrus concentrate Canned fruit Sweets	Not provided	Not provided	Fruit juice (EU): 6.5 Canned fruit (EU): 3.25 Canned fruit (US): 5.8 Frozen fruit/vegetables (US): 9.4
3013.8	Jams	1.58 p/d	Not available	Jams (EU): 6.0
3013.9	Frozen potato products	560 p/d 143 018 p/a	6.2	Frozen fruit/vegetables (US): 9.4 Frozen vegetables (EU): 9.4
3013.10	Canned vegetable products	14 400 p/a	1.6	Canned vegetables (EU): 4.75 Canned tomato (US): 2.93
3013.11	Frozen vegetables	188,976 p/a	3.3	Frozen fruit/vegetables (US): 9.4 Frozen vegetables (EU): 6.75
3013.12	Canned/bottled piquanté peppers and other vegetables	300 p/d 78 545 p/a	19.2	Canned vegetables (EU): 4.7 Canned tomato (US): 2.93
3103.13	Deciduous fruits and vegetables	553 824 p/a	6.16	Canned oranges (China): 30 Canned fruit (US): 5.8 Canned fruit (EU): 3.25 Canned vegetables (EU): 4.75
3013.14	Tree fruits	60 p/d	15	Dehydrated fruit (USA): 0.3
3013.15	Canned peppers and sorbet	6 000–13 000 p/m	Not available	Frozen fruit/vegetables (US): 9.4 Canned vegetables (EU): 4.75
3013.16	Apple concentrate	300 000 p/a 1 650 per day	22.38	Fruit juice (EU): 6.5 Fruit juice (UK): 3.5
3013.17	Pineapple concentrate	101 164 p/a	10.15	Fruit juice (EU): 6.5 Fruit juice (UK): 3.5
3013.18	Canned peppers and vegetables	17 700 p/a	5.9	Canned vegetables (EU): 4.7
3013.19	Citrus concentrate	90 918 p/a	Not provided	Fruit juice (EU): 6,5 Fruit juice (UK): 3.5

For the industries that were visited and surveyed, and the literature, the average specific water intake (SWI) figures for the canning process were found to be 6.81 m^3/ton raw material and 8.22 m^3/ton of product, 3.79 m^3/ton raw material and 4.45 m^3/ton of product for juicing, 16.3 m^3/ton raw material and 4.8 m^3/ton of product for freezing, and 1.3 m^3/ton raw material and 15.0 m^3/ton of product for drying. The average SWIs for all these processing types were 6.71 m^3/ton raw material and 7.96 m^3/ton of product. The corresponding SWI values that were reported in the first version of the NATSURV for the FVPI (1987) were 8.79 m^3/ton for canning, 1.29 m^3/ton for juicing, 14.5 m^3/ton for freezing, and an average of 9.29 m^3/ton for all the process types (all expressed in terms of tons of raw material). Drying processes were not reported on in the 1987 version of FVPI NATSURV.

CHAPTER 6: WASTEWATER GENERATION AND MANAGEMENT

6.1 WASTEWATER GENERATED IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

Fruit and vegetable processing effluent can be characterised by organic pollution, with high BOD, COD, and TSS levels (Table 6.1). Although the wastewater is generally less polluted than that of other industries, it does usually require treatment before discharge is possible (Valta et al., 2017).

Table 6.1: Physiochemical characteristics of different effluent streams in the FVPI (Valta et al., 2017; Guzmán et al., 2016; Amor et al., 2012; El-Kamah et al., 2010; Şentürk et al., 2010)

Processing type	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	pH
Tomato processing	500	1 500	400	6.5–8
Fresh and frozen peaches/apricots	1 100	2 300	900	-
Peach and apricot compote	1 300	1 800	460	-
Canned and pureed peaches/apricots	1 750	3 500	500	7–8.5
Canned and pureed peaches/apricots	1 200	4 000	800	6–8
Citrus juice	6 619	10 019	777	3.8
Fruit juice	1 289	5 157	323	-
Citrus concentrate	13 900	21 040	31,30	3.45
Potato processing	4 000–5 000	5 250–5 750	2 000–2 100	7–8

According to the Emission Limit Guidelines for Fruit and Vegetable Processing Activities that Discharge Pollutants Into Fresh And Marine Waters (Tasmania Department Of Primary Industries, Water & Environment, 1997), wastewater characteristics will vary depending on the following:

- Quality of influent water
- Rate of water consumption
- Type of fruit or vegetable processed
- Condition (ripeness, damage) of raw product

- Whether the product is conveyed by a wet or dry process
- Processing techniques (washing, blanching, peeling, etc.)
- Whether brine, caustics, and other chemicals are used in processing
- Clean-up methods (dry vs. wet, detergents, disinfectants)
- Frequency and duration of shutdowns
- Condition and type of equipment
- Management and staff training

6.2 ENVIRONMENTAL CONSIDERATION: ISO 14000

ISO 14000 is a series of standards pertaining to the environmental management of organisations. These standards and guidelines can be divided into three broad categories: evaluation and auditing tools, management systems standards, and product-oriented support tools (Wall et al., 2001). Included in the ISO 14000 series is the ISO 14001 standard, which is regarded as one of the most important standards within the series. ISO 14001 often serves as the principal set of standards utilised by facilities when designing and implementing effective environmental management systems (EMS). However, the ISO 14001 does not contain specific requirements for environmental performance, but rather provides a framework for facilities in order to set up an effective EMS. The ISO 14001 is based on the principles of the plan-do-check-act (PDCA) cycle, which entails the following (Martin, 1998):

- **Plan: Identifying objectives and processes required**

  Before ISO 14000 can be implemented, an initial review of the facility's processes and products should be conducted. This is done to identify all the 'environmental aspects' of the current process and, if possible, future processes.

- **Do: Implementation of the processes**

  During this phase, the facility identifies the resources required for an effective EMS. Individuals responsible for the implementation and control of the EMS are also identified.

- **Check: Monitoring processes and reporting results**

  This stage requires the facility to monitor the performance of the processes implemented, to ensure that their targets are being met.

- **Act: Improve performance of EMS**

  After the monitoring stage, a review should be conducted to determine whether the predetermined objectives and targets are being met, as well as to which extent they are being met. The review should also take changing circumstances, such as legal requirements, into consideration. After the review has been conducted, measures should be taken to improve the EMS for future processes.

In addition to these basic steps, the ISO 14001 also encourages facilities to make continuous improvements to their environmental performance. Apart from reducing the facility in question's environmental impact, the implementation of the ISO 14000 may also yield economic benefits – due to the ISO 14001 being an internationally recognised standard. Thus, ISO 14001 certification provides facilities with better international trading opportunities as well as an enhanced competitive advantage over facilities who do not have this certification (Wall et al., 2001).

6.3 OVERVIEW OF WASTEWATER TREATMENT PROCESSES IN THE FVPI

The wastewater streams are typically separated before treatment (IPPC, 2006), with treatments categorised as primary, secondary, or tertiary treatments. The three levels of treatments are briefly discussed below.

6.3.1 Primary treatment

Primary treatments include those processes that reduce floating or suspended solids in wastewater by mechanical or gravitational methods (Patel and Vashi, 2015). During this treatment phase, approximately 25–50% of the preliminary BOD, 50–70% of the TSS and 65% of the oil and greases are removed (Sonune and Ghate, 2004).

6.3.2 Secondary treatment

Secondary treatment, also termed biological treatment, seeks to remove suspended solids by microorganisms under either aerobic or anaerobic conditions (Samer, 2015). During the biological processes, the organic matter is either oxidised or incorporated into cells, which can later be removed by sedimentation (Samer, 2015). Secondary treatments found to be suitable for the FVPI can be viewed in Table 6.2.

Aerobic processes use mostly bacteria, protozoa, rotifers and fungi to accomplish the oxidation of organic material (Taricska et al*.,* 2008). Suspended growth processes, attached growth processes, or a combination of both can be used to accomplish the treatment (Taricska et al*.,* 2008). The aerobic processes may however contribute to odour problems and can be energy-consuming and costly (Liu et al., 2009) A potential solution to this may be anaerobic digestion processes, with the added benefit of energy production. The following three separate chemical/biochemical reactions are needed for the complete anaerobic oxygenation of organic waste (Hung et al*.,* 2008):

- **Hydrolysis**: Decomposition of large organic molecules by bacteria into monomers such as sugars, fatty acids, and sugars
- **Fermentation**: The biochemical conversion of carbohydrates into alcohols or organic acids
- **Methanogenesis**: The conversion of organic acids to methane by methanogenic bacteria

Aerobic and anaerobic treatments can also be combined in the form of membrane bioreactors (MBR), which can operate in either aerobic or anaerobic mode (IPPC, 2006).

6.3.3 Tertiary treatment

Secondary treatment has often proven to be insufficient in protecting the receiving waters or in providing water for recycling purposes (Sonune and Ghate, 2004). Tertiary treatment can thus be used and is considered a 'polishing' step (IPPC, 2006). Table 6.2 provides a description of wastewater treatment options found suitable for the FVPI by the IPPC (2006). The treatment processes, together with their applications and advantages and disadvantages, are further discussed in Section 6.4.

Table 6.2: Suitable wastewater treatment options for the fruit and vegetable processing industry (IPPC, 2006)

Treatment options	Description	Additional References
Primary treatment options		
Screening	Static, vibrating, or rotary screens are devices with small openings that remove coarse solids from wastewater	Valta et al. (2017)
Flow and load equalisation	Equalisation/buffer tanks are used to cope with variability in flow and composition	
Neutralisation	The addition of chemicals or mixing of separate wastewater streams to avoid highly acidic or alkaline discharge and to protect downstream treatments	
Sedimentation	Separation, by gravity, of suspended particles heavier than water, followed by subsequent removal of the sediment from the bottom of the tank	Valta et al. (2017); Pfitzmann (1983) in Casani et al. (2005)
Dissolved air flotation (DAF)	Fine air bubbles attach themselves to chemically conditioned particles, which then assist the particles in rising to the surface	Valta et al. (2017)
Centrifugation	Solid bowl, decanter, disk-nozzle, and basket centrifuges result in reduced FOG, COD/BOD, and SS	Galanakis (2012)
Precipitation	Dissolved substances are chemically treated to allow conversion into insoluble particles, following which they are removed by sedimentation or DAF	Valta et al. (2017); Amor et al. (2012)

Secondary aerobic treatment options		
Activated sludge	Activated mass of microorganisms aerated and maintained in suspension within a reactor vessel	Valta et al. (2017); Koppar and Pullammanappallil (2013); Amor et al. (2012); Ozbas et al. (2006)
Pure oxygen system	Essentially an intensified activated sludge process (i.e. injection of pure O_2 into the reactor vessel)	Sterritt and Lester (1982)
Sequencing batch reactors (SBR)	Another variant of the activated sludge process that operates according to a fill-and-draw principle	Tawfik and El-Kamah (2012); Ozbas et al. (2006)
Aerobic lagoons	Large, shallow dams used for the natural aerobic treatment of wastewater	Koppar and Pullammanappallil (2013)
Trickling filters	Biomass is grown as a film on the surface of packaging media, with the wastewater allowed to flow evenly across it	Koppar and Pullammanappallil (2013); Chowdhury et al. (2010)
Bio-towers	Specially designed trickling filters operated at high organic loading rates	
Rotating biological contactors (RBC)	The unit consists of a series of closely spaced and submerged plastic discs covered with biomass	Najafpour et al. (2006)
Biological aerated flooded filters (BAFF) and submerged biological aerated filters (SBAF)	Activated sludge systems with high voidage media that encourages biological growth and a degree of physical filtration	
High rate and ultra-high rate aerobic filters	The system uses a high wastewater recycling rate directed through an integral nozzle. The nozzle provides intensive oxygenation, and high shear force on bacterial cultures	

Secondary anaerobic treatment options		
Anaerobic lagoons	Similar in construction to aerobic lagoons, with the exception of mixing/aeration to allow for an anaerobic environment	Koppar and Pullammanappallil (2013)
Anaerobic contact processes	Analogous to the aerobic activated sludge process, with the difference being that the reactor is sealed off from the entry of air	
Anaerobic filters	The growth of anaerobic biomass is established on a packaging material, with wastewater allowed to flow over it	Rajinikanth et al. (2009)
Up-flow anaerobic sludge blanket (UASB)	Wastewater is directed to the bottom of a reactor, where it passes through a blanket of bacterial granules. Natural convection raises a mixture of gas, treated water, and sludge granules to the top of the reactor, where a three-phase separator is used to separate the final effluent from the solids.	Ozbas et al. (2006); Sigge and Britz (2007); Koppar and Pullammanappallil (2013)
Hybrid UASB reactors	A variation of the conventional UASB that incorporates a packed media zone above the main open zone. The packed zone assists in the collection of non-granulated bacteria which, in a conventional UASB reactor, would have been washed out.	
Fluidized and expanded bed reactors	With a fluidised bed reactor, the carrier material is constantly in motion and kept in suspension by using high circulation rates. An expanded bed reactor uses light materials to minimise the up-flow velocities required to fluidise the beds.	
Internal circulation (IC) reactors	An adjusted configuration of the UASB, in which two UASB compartments are placed on top of each other (one with a high loading, the other with a low loading). Biogas collected in the first stage drives a gas-lift, resulting in internal recirculation of wastewater and sludge.	

Expanded granular sludge bed reactors (EGSB)	EGSB reactors use the type of granular sludge found in in UASB reactors, but operate at a much greater depth of granular sludge, with a higher water rise rate	
Tertiary treatment options		
Biological nitrification/denitrification	A variation of the activated sludge process	
Ammonia stripping	Biological as well as physio-chemical processes are available for the purification of highly nitrogenous wastewater streams	
Biological phosphate removal	Microorganisms in the sludge are stressed in order to induce more phosphorous absorption for biological growth	
Hazardous substance removal	Removal of many hazardous substances is usually achieved through appropriate use of treatments like sedimentation, precipitation, filtration, and membrane filtration. Further treatments such as **carbon adsorption** and **chemical oxidation** can also be applied	Wu et al. (2016)
Filtration	Filters may be of the gravity- or pressure-driven type, with **standard sand** or **dual media** filters (sand/anthracite) being common	
Membrane filtration	Membrane filtration is based on using a pressure-driven, semi-permeable membrane in order to achieve selective separation based primarily on pore-size	
Biological nitrifying filters	Although ammonia usually removed during secondary biological treatment, it is also common to install separate tertiary biological nitrifying filters. Variations of the standard percolating or high rate aerobic filters are commonly used.	
Disinfection and sterilisation	Biocides (e.g. chlorine, ozone, etc.) and UV radiation are commonly used methods for sterilisation/disinfection	Wu et al. (2016); Valta et al. (2017)

6.4 WASTEWATER TREATMENT PROCESSES APPLIED IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

6.4.1 Primary Treatment Options

Primary treatments are mainly focused on the removal of organic and inorganic solids that are readily settled by means of gravity, or those which are able to float (FAO, 1992). Possible primary treatment options include the following:

Screening

Screening is responsible for removing solids such as foreign objects or organic materials. The screening unit generally consists of parallel rods, bars, wires, or perforated plates (Spellman, 2016; IPPC, 2006). The spacing between the gratings may vary based on the type of screening desired. For example, when screening for coarse materials, a spacing of 20–60 mm may be used – while for finer screening processes a spacing of no greater than 5 mm is used (IPPC, 2006). The main types of screening being used in industry include the following (Kutz, 2018; PPC, 2006):

- **Vibrating screens** are largely used for treatments associated with by-product recovery – more specifically solids with a low moisture content. For this screening method to be effective, rapid motion is required. Vibrating screens often operate between 900 and 1 800 rpm. The screening surface generally consists of one or more decks; the use of more than two decks is rarely observed. When selecting an appropriate fine vibrating screen, it is important to consider the combination of wire strength and open area percentage being applied. The percentage of open area of the screening medium is the determining factor of the capacity of a vibrating screen. The efficiency of vibrating screens is influenced by various factors, including the composition of the solid waste, shape and size of particles, feed rate, stroke length and vibration frequency, ratio of length to width, and the slope of the screen (Kutz, 2018). Vibrating screens are best suited for relatively dry and granular mixtures. The use of these systems is rarely seen in the fruit and vegetable processing industry, as this method is susceptible to clogging and does not operate efficiently when separating wet materials (Kutz, 2018).

- **Rotary or drum screens** are specifically effective for effluent streams with high solids content. Rotary screens are a popular form of screening devices due to their effectiveness, efficiency, and clogging resistance – which can be attributed to their design and operation (Kutz, 2018). Wastewater passes through one end of the screen and solids are dispensed at the other end. Microscreens are used for the separation of solid particles from the wastewater. It has been reported that optimal separation is accomplished at an operating pressure of 5–10 mbar.

- **Static screens** often comprise vertical bars or a perforated plate. Static screening requires manual or automatic cleaning processes.

Flow and load equalisation

Storage tanks, also known as equalisation tanks, are often used to manage the variability observed in the flow and composition of wastewater. Thus, these tanks may be used to ensure that a steady throughput is maintained and ultimately aim to improve the effectiveness of secondary or advanced wastewater treatment processes (Rathoure and Dhatwalia, 2016; Chang and Li, 2006). Alternatively, they are used to provide corrective treatments, such as pH adjustment or chemical conditioning (Rathoure and Dhatwalia, 2016). Load equalisers aim to provide secondary and advanced treatment processes with wastewater that has uniform properties. This is done to ensure that a uniform and effective treatment may be applied to the wastewater. Thus, flow and load equalisation processes aim to improve the efficiency of secondary wastewater treatment processes (IPPC, 2006).

Neutralisation

This process is often applied in the fruit and vegetable processing industry. The main objective of neutralisation is to prevent the discharge of wastewater that is strongly acidic or alkaline (Rathoure and Dhatwalia, 2016). Neutralisation may be carried out in a holding tank, rapid mix tank, or equalization tank – to maintain a pH of between 6 and 9 (Rathoure and Dhatwalia, 2016). This process further provides protection for downstream treatment operations. Naturally, the treatments used differ based on the pH of the wastewater (IPPC, 2006).

Neutralisation of acidic wastewater involves the following:

- Addition of limestone, limestone slurry, or milk of lime
- Addition of sodium carbonate (Na_2CO_3) or caustic soda (NaOH)
- Use of cationic ion exchangers

Neutralisation of alkaline wastewater involves the following:

- Addition of CO_2, such as through flue gas and gas obtained from fermentation processes
- Addition of hydrochloric acid (HCl) or sulphuric acid (H_2SO_4)
- Use of anionic ion exchangers

This treatment method prevents the negative effect associated with strongly acidic or alkaline wastewater, namely the reduction of biological treatment efficiency and/or increased corrosion (IPPC, 2006).

Sedimentation

Sedimentation is often used in operations that produce wastewater containing large amounts of (settled solids (SS), including in the fruit and vegetable processing industry (IPPC, 2006). Sedimentation involves the separation of SS from water by allowing the SS to settle through gravity (Rathoure and Dhatwalia,

2016. The SS may then be removed in the form of sludge. The sludge produced during sedimentation is often recoverable as a by-product that can be used for other purposes, such as animal feed (IPPC, 2006).

While the sedimentation unit is simple to install and relatively reliable, the process does have some disadvantages. The sedimentation tanks require large surface areas, the process is not suitable for finely dispersed materials, and the laminar separators are often prone to blockages with fat (IPPC, 2006).

Dissolved air flotation (DAF)

In comparison to sedimentation, DAF requires a smaller surface area, provides a higher separation efficiency, and can absorb shock loads. DAF introduces small air bubbles into wastewater containing suspended solids (Rathoure and Dhatwalia, 2016). The air bubbles are then able to attach to particles, which have been chemically conditioned; as the bubbles then rise to the surface, so do the solids (IPPC, 2006). The float is frequently removed from the surface of the tank (Rathoure and Dhatwalia, 2016). The air is dissolved into the wastewater under pressures of 300–600 kPa.

DAF allows for the reduction of free BOD, COD, SS, nitrogen, and phosphorous levels. As with sedimentation, the sludge acquired during treatment may be recoverable as a by-product (IPPC, 2006).

Centrifugation

Centrifugation is often applied for thickening or dewatering purposes. The centrifugal forces created when the centrifuge rotates at high speeds ensure that the sedimentation process is accelerated (Strande et al., 2014). Four types of centrifuges are available in industry: **solid bowl**, **basket**, **disc-nozzle,** and **decanter**. Solid-bowl centrifugation requires the supernatant liquors to be removed from the surface, while the basket system makes use of a perforated mesh that allows the liquids to pass through the screening medium during centrifugation. Disc-nozzle centrifugation is mostly used in processes where liquid/liquid separation is required. Decanter centrifuges are often used for the separation of activated sludge (IPPC, 2006).

Precipitation

Precipitation may be used in cases where suspended solids cannot be separated from wastewater by means of gravity. The primary targets of precipitation are SS and phosphorous. The process of precipitation consists of three stages: The first stage involves coagulation, which is carried out to disrupt the colloidal system by lowering the potential responsible for the stability of the system. This is usually accomplished by dosing the wastewater with inorganic chemicals such as ferric chloride, aluminium sulphate, or lime (Prazeres et al., 2019; IPPC, 2006). The second stage involves flocculation of the smaller particles into larger particles, which are readily able to settle or float. Polyelectrolytes may be added, to assist with bridge formation between particles to eventually produce large flocs. In some cases, the precipitation of metal hydroxides may occur; these hydroxides are able to adsorb fat particles. In the third stage, once precipitation has been completed, the sludge is removed by means of sedimentation or DAF (IPPC, 2006).

6.4.2 Secondary treatment options

The primary focus of secondary treatments is the removal of biodegradable organic matter as well as SS by means of biological methods (IPPC, 2006). The organic sludge produced during the treatments is also responsible for the adsorption of non-biodegradable compounds such as heavy metals. It is possible to use either a single secondary treatment or a combination of methods based on the wastewater characteristics as well as the requirements before discharge (IPPC, 2006). Processes where secondary treatments are used in combination are often referred to as multistage systems (IPPC, 2006). The main types of metabolic processes utilised in secondary treatments are aerobic and anaerobic processes.

6.4.2.1 Aerobic processes

Aerobic processes are often only used when the wastewater in question is readily biodegradable (IPPC, 2006). During these processes, digestion takes place in the presence of oxygen. A combination of autotrophic and heterotrophic microorganisms is often used to accomplish the aerobic digestion (Aziz et al., 2019). Microorganisms in suspension are provided with oxygen by means of submerged diffusers or a surface input. Oxygenation cages or surface aerators may be used to inject oxygen into the suspension from the surface (IPPC, 2006). The advantages and disadvantages of aerobic treatments are displayed in Table 6.3.

Table 6.3: Advantages and Disadvantages of aerobic treatment processes (IPPC, 2006).

Advantages	Disadvantages
• Degrades organic matter into harmless compounds	• Produces large amounts of sludge • Digestion results in fugitive releases that may cause odours • Bacterial activity decreases at low temperatures • FOG needs to be removed prior to initiation of aerobic biological treatment, as it could lower the efficiency of the WWTP since it is not readily degradable by bacteria

Activated sludge

The activated sludge process is characterised by its ability to produce an activated mass of microorganisms that can stabilise waste in the presence of oxygen. The activated sludge process allows operators to reduce the COD/BOD, nitrogen, and phosphorus levels of wastewater (IPPC, 2006). After the retention period, the microbial biomass and treated liquid are separated (Sigge, 2005). The biomass is often maintained in suspension within a reactor vessel, where it is further supplied with oxygen. This process is divided into two distinct phases, which are generally performed in separate basins, namely aeration and settling (Paulsen, 2006; Sigge, 2005).

Aerobic oxidation takes place within the aeration basin. During this phase, the organic matter is degraded to CO_2, H_2O, ammonium (NH_4), and new biomass (Paulsen, 2006; Sigge, 2005). The suspension within the aeration basin is known as mixed liquor (ML). Aeration serves two functions within this process: firstly, supplying the aerobic microorganisms with oxygen and, secondly, ensuring the constant agitation of the activated sludge flocs (Paulsen, 2006). Agitation ensures that sufficient contact between the flocs and incoming wastewater takes place. Aeration is regarded as the main energy consumer of the activated sludge process, due to oxygen being supplied by mechanical means on a continuous or semi-continuous basis. Due to the aerobic conditions, energy may be recovered in terms of biomass per unit substrate processed. However, this results in a large amount of sludge production, which requires further processing and disposal. Sludge production is largely responsible for the major operating expenses of this procedure and is further regarded as its main disadvantage (Deepnarain et al., 2019; Paulsen, 2006).

The retention times of the biomass within the reactor vessels may vary from several hours to more than 10 days. Generally, a loading rate or F/M ratio of 0.1–0.15 BOD/kg MLSS per day is used (von Sperling, 2007; IPPC, 2006). After this predetermined retention period, the mixed suspension of microorganisms is passed to a sedimentation facility. The F/M ratio and hydraulic retention time (also known as sludge age) may vary based on multiple factors. These factors include the characteristics of the raw wastewater, such as its composition and the degradability of organic material, and the quality required for the final wastewater. For instance, nitrification only occurs at low loading rates (<0.1 BOD/kg MLSS per day) (von Sperling, 2007; IPPC, 2006). Once in the sedimentation facility, the microbial flocs start to settle and the clear wastewater passes over a weir and on to a watercourse. Most of the settled sludge produced is returned to the aeration tank. However, in order to maintain the MLSS at an acceptable level (e.g. 3 000 mg/L), the excess sludge is wasted (von Sperling, 2007; IPPC, 2006).

Bulking is a problem commonly associated with the activated sludge process. More specifically, it is often observed in processes treating high-carbohydrate wastes, such as those found in fruit and vegetable canneries (Sigge, 2005). Bulking describes biological sludge that possesses poor settling characteristics. It is generally observed due to excessive water binding within the biological flocs and/or the presence of filamentous bacteria (IPPC, 2006). It is important to note that when considering the bulking of sludge, prevention is better than curing the problem. This is because various chemicals may be used as a cure for bulking. However, these curing methods are usually not highly selective and may lead to the destruction of the entire biological activity (IPPC, 2006). The prevention of bulking may be accomplished by various methods, including maintaining an optimum balance of added nutrients and minimising the overproduction of filamentous bacteria. Load reduction has been reported as an acceptable method to manage the effects of bulking once it has occurred. The operating temperatures, hydraulic retention time, and sludge age are the most important factors to consider when dealing with the bulking of sludge (von Sperling, 2007; IPPC, 2006).

In addition to the abovementioned processes, the use of a selector has been recognised as an acceptable method to prevent and control the growth of filamentous bacteria. This process involves the selective growth of floc-forming organisms; this is accomplished by supplying the wastewater with high F/M ratios at controlled dissolved oxygen levels. The contact time for this process is generally short, with a typical range of 10–30 minutes (von Sperling, 2007; IPPC, 2006).

It has been reported that the activated sludge process is able to reach phosphorus removal efficiencies of about 10–25% (IPPC, 2006). Furthermore, it has been found that this process can treat wastewater with high or low BOD levels, but the treatment of low BOD water yields higher efficiencies and is more cost effective. The application of this method may however be limited due to its space requirements (IPPC, 2006).

Sequencing batch reactors

The sequencing batch reactor (SBR) process is a variation of the activated sludge process. This process generally consists of two identical reaction tanks and its operation is based on the fill-and-draw principle. Multiple stages of the activated sludge process occur within the same reactor (WEF, 2018).

This process is regarded as being very flexible since it is possible to make several process changes within the operating cycles – such as improved denitrification during the stationary phase. The cycle period typically lasts about six hours. However, the time taken for each stage within the process may be adjusted to suit the requirements. Furthermore, the process is not dependent on influences caused by the fluctuations of hydraulic input. This means that SBRs are simpler and more robust in comparison to conventional activated sludge processes (WEF, 2018; IPPC, 2006).

SBRs can treat high- and low-BOD wastewater, but a higher-efficiency cost effectiveness is accomplished when treating low-BOD wastewater. SBR is also suitable for treating industrial wastewater with a tendency towards bulking sludge. This is because this process makes use of batch-wise filling, which allows for the formation of readily settling activated sludge (IPPC, 2006). The SBR is typically used in small-flow operations, which produce around 4 000 m^3 wastewater per day. Thus, it is typically applied as an extended aeration system (WEF, 2018). Similar processes with larger capacities do however exist, with capacities ranging from 150 000–700 000 m^3 of wastewater produced per day (WEF, 2018). The SBR process requires lower capital, but higher operating costs in comparison to conventional activated sludge processes (IPPC, 2006).

Aerobic lagoons

Aerobic lagoons can be described as large, shallow, earthen basins used for treating wastewater by means of natural processes. They generally involve the use of bacteria, algae, the sun, and wind. The algae and bacteria are suspended in the lagoon while aerobic conditions are maintained throughout the entire lagoon. Oxygen may enter the system by means of mechanical or atmospheric diffusion; however, it may also be produced by algae (Paulsen, 2006; IPPC, 2006). Pumps or surface aerators are usually used to mix the contents of the lagoons (IPPC, 2006).

Aerobic lagoons can be divided into two basic types with different objectives: The first operation is mainly focused on maximising the production of algae; the design used during this process is generally limited to pond depths of 150–450 mm. The second type is aimed at maximum oxygen production, using pond depths of up to 1.5 m (Paulsen, 2006).

Aerobic lagoons aim to reduce the nitrogen and BOD levels within the wastewater. This process may however lead to soil degradation, contamination of groundwater, and the production of unwanted odours (IPPC, 2006). Due to the low solids maintained in the system, aerobic lagoons are often operated at high organic loadings (Sigge, 2005).

When applying this technique to processes within the fruit and vegetable industry, the lagoons should have sufficient capacities to prevent uncontrolled overflows. The lagoons should also allow for the controlled discharge of wastewater during periods when high flow is experienced (IPPC, 2006). Furthermore, it has been reported that the aerated lagoons were able obtain 95% BOD removal efficiencies (Manivasakam, 2013; Sigge, 2005).

Trickling filters

Trickling filters, also referred to as biofilters or percolating filters, are an example of a fixed film aerobic process (Manivasakam, 2016). During this procedure, wastewater – after being subjected to a primary treatment – is passed over a bed of broken rocks. The biomass formed on the surface of these stones oxidises the wastewater as it passes across the film (Manivasakam, 2016; IPPC, 2006). Trickling filters generally consist of a circular or rectangular tank containing the filter medium (stones, plastic media, treated wood, or hard coal) with a bed depth of 1.0–3.0 m. This ensures that a large surface area is available for maximal microbial growth and film formation (Manivasakam, 2016; Sigge, 2005). Furthermore, it should also be sufficiently porous to allow air and sloughed microbial biofilm to pass through.

The selection of filter media is generally based on various factors, including specific surface area, unit weight, and void space, as well as media configuration, size, and cost. For example, smaller filter media provide a larger surface area for biofilm formation, but this also results in a smaller void space (Sigge, 2005). Plastic media usually consist of polyvinylchloride (PVC) or polypropylene (PP) and are primarily applied in high-rate trickling filters. They have a low bulk density and provide an optimum surface area (85–140 $m^2.m^{-3}$) as well as a higher void space (up to 95%) in comparison to other media (Manivasakam, 2016; Sigge, 2005). Therefore, this media reduces clogging. Since plastic is a lightweight material, it requires less heavily reinforced concrete tanks than observed when making use of stone media.

Generally, an underdrain system is included to collect the treated wastewater and biomass that have been sloughed from the biofilm material. Finally, a separation tank, also known as a humus tank, is required to separate the solids from the treated wastewater (Manivasakam, 2016; Sigge 2005). A portion of the treated liquid is recycled within these settling tanks to dilute the incoming wastewater (IPPC, 2006).

Trickling filters are generally applied to reduce the BOD/COD, phosphorus, and nitrogen levels of wastewater. Organic loading rates associated with this method may vary, with the typical loading rate being 0.5 kg $BOD.m^{-3}.d^{-1}$. Low-rate filters may exhibit loading rates of 0.1–0.4 kg $BOD.m^{-3}.d^{-1}$, while high-rate filters exhibit loading rates of 0.5–1.0 $kgBOD.m^{-3}.d^{-1}$ (Sigge, 2005). BOD removal by means of trickling filters is around 85% for low-rate filters, while high-rate filters show BOD removal rates of 65–75% (Sigge, 2005). Trickling filters are however generally only used for wastewater with relatively low BOD levels, since high organic loads may cause filter blockages because of excessive biofilm formation (IPPC, 2006; Sigge, 2005). To ensure that the process operates at optimal efficiency, it is important to minimise FOG levels before the wastewater is fed into the high-rate filter. In certain cases where high effluent quality is required, a secondary sedimentation process may be applied after high-rate filtration (IPPC, 2006).

Biological aerated flooded filters (BAFF) and submerged biological aerated filters (SBAF)

BAFFs and SBAFs are fixed-film systems that entail submerging a biofilm support medium in wastewater to provide a large contact surface for aerobic biological treatment (Hodkinson et al., 1999). BAFFs often use media with high specific surface areas and low voidage. The surface-area requirement is usually very low and organic loading rates may be in excess of 10 kg $COD.m^{-3}.d^{-1}$. Due to the high level of solid retention and the development of biomass, a regular backwashing step is required to remove the accumulated solids. SBAFs are essentially BAFFs that make use of high-voidage media (typically < 400 $m^2.m^{-3}$), but do not require a backwashing step, as the accumulated solids in the reactor are controlled by biomass sloughing and air-scouring (Hodkinson et al., 1999). By eliminating the backwashing process, the construction and operational costs are reduced. SBAFs are generally suitable for small plants where robust, simple, and compact treatment is desired. An SBAF is usually used to treat settled wastewater and often requires secondary sedimentation (Hodkinson et al., 1999). Typically, these systems are primarily used as a polishing phase in domestic wastewater treatment processes; however, the use of SBAF has increased in the FDM sector.

High rate and ultra-high-rate aerobic filters

The use of high rate and ultra-high-rate filters allow aerobic systems to accommodate higher loading rates than usual, with ultra-high-rate filter systems providing the potential for loading aerobic systems 50 to 100 times more than conventional aerobic processes (IPPC, 2006). This is because these processes use media such as PVC that can minimise clogging issues and provide a large surface area for biofilm formation (Jeong et al., 2019; Manivasakam, 2013). These processes involve a high wastewater recycle rate, which is directed through a nozzle assembly. The nozzle provides the system with air, which provides a high shear force on the bacteria in the system. It also yields a high degree of oxygenation (IPPC, 2006).

High-rate and ultra-high-rate filters are mainly concerned with the reduction of BOD and COD levels within the wastewater. However, due their high throughput rates they generally do not yield a wastewater quality that is sufficient for discharge to rivers; thus, an additional aerobic phase, which is loaded more conservatively, is often required (Manivasakam, 2013; IPPC, 2006).

6.4.2.2 Anaerobic processes

Anaerobic wastewater treatment processes entail the breaking down of organic matter in the absence of oxygen, often leading to the production of CO_2 and methane (CH_4) as by-products (IPPC, 2006; Paulsen, 2006). In certain variations of the anaerobic processes, the produced methane may be used as a fuel source. Standard anaerobic reactors are generally unheated, while high-rate anaerobic processes make use of heated reactors. In both cases, the temperature of the reactors needs to be maintained at approximately 30–35°C for standard processes or 45–50°C when using high-rate processes (Manivasakam, 2013; IPPC, 2006).

Even though microbial growth is slower under anaerobic conditions, higher BOD loadings are achievable in comparison to aerobic techniques. Anaerobic processes are typically applied in industries with a high level of soluble and readily biodegradable organic material as well as wastewater strength, which, when expressed in COD, is greater than 1500–2000 mg/L (IPPC, 2006). In the food, drink, and milk industry, anaerobic processes are generally only applied when treating wastewater with a COD of approximately 3000–4000 mg/L – which is commonly observed in the sugar, starch, fruit, and vegetable industries.

Anaerobic lagoons

Anaerobic lagoons serve as both sedimentation basins and anaerobic treatment devices for high-strength organic wastewater with a high concentration of solids (Paulsen, 2006). These lagoons are generally deep, earthen basins with appropriate inlet and outlet piping, and they may have a depth of 2.5–9.0 m to ensure that anaerobic conditions are maintained throughout the lagoon as well as to ensure the conservation of heat energy (Cheremisinoff, 2016; Paulsen, 2006; Sigge, 2005).

In anaerobic lagoon systems, organic matter is converted to CO_2, CH_4, and other gases, such as hydrogen sulphide (H_2S), as well as organic acids and cell biomass (Paulsen, 2006; Sigge, 2005). Conversion efficiencies ranging from 75–85% have been reported when operating at optimal conditions (Paulsen, 2006). The minimum organic loading level generally required to reach totally anaerobic conditions in a lagoon is 100 g $BOD_5.m^{-3}.d^{-1}$. For optimal performance systems should be maintained at conditions which are favourable to the methanogenic bacteria present in the lagoons. It is necessary to keep the temperature of the system in the range of 25–40°C. A rapid decrease in anaerobic activity is observed at temperatures below 15°C, with activity being virtually halted once temperatures drop below 10°C (Cheremisinoff, 2016; Paulsen, 2006). Naturally, this process comes with its own unique advantages and disadvantages, which are summarised in Table 6.4.

Table 6.4: Advantages and disadvantages of anaerobic lagoons (Cheremisinoff, 2016)

Advantages	Disadvantages
• More effective for rapid stabilisation of strong organic wastes; allows for higher influent organic loading	• Requires relatively large area of land
• Produces CH_4 as by-product, which can be used to generate electricity for other processes within the facility	• May produce undesirable odours (due to production of H_2S)
• Produces less biomass per unit of organic material processed	• Relatively long retention time required for organic stabilisation
• Does not require additional energy, since systems are not aerated, heated, or mixed	• Wastewater may cause ground degradation or affect underground water quality
• Lower construction and operation costs than other methods	• Environmental conditions directly impact the operation of this system
• Lagoons may be operated in series	

Anaerobic contact processes

Anaerobic contact processes may be associated with the activated sludge process, since the separation and recirculation of biomass is incorporated into the design (IPPC, 2006). The influent waste passes through a contact reactor which contains a high concentration of active biomass. A downstream clarifier is responsible for removing the active biomass from the effluent stream to recycle the biomass back to the contact unit (Show, 2008). This method is generally applied when treating wastewater that contains high-strength soluble wastes. The fact that this technique is relatively simple to execute and does not result in high levels of clogging is arguably the main driving force behind its implementation (IPPC, 2006). Contact stabilisation processes usually do not produce biomass concentrations as high as observed in other high-performance processes. Thus, this process can accommodate a relatively low organic loading of up to 5 kg COD/m^3 per day (IPPC, 2006).

Anaerobic filters

In anaerobic filters, as with aerobic filters, microbial growth is established on a packaging material (Stanbury, 2017; IPPC, 2006). The packaging material is responsible for retaining the biomass within the reactor and it further assists with the separation of the gas from the liquid phase. This system may be adapted to operate in an upflow or downflow mode, with a wide variety of packaging materials available (Stanbury, 2017; IPPC, 2006). The average specific surface area of the packing utilised in this process is about 100 $m^2.m^{-3}$. Anaerobic filters that are suitable for the treatment of wastewater contain a COD level of 10 000–70 000 mg/L (IPPC, 2006). Stanbury (2017) reported that this technique has been applied for the treatment of effluents originating from various processes, including citric acid fermentation wastes, molasses distillery slops, domestic effluents, food canning, and soft drink wastes.

Upflow anaerobic sludge blanket (UASB)

In this system, high levels of active biomass are retained through the formation sludge granules – a process also known as flocculation (Stanbury, 2017; van Schalkwyk, 2004). The UASB reactor is divided into the following three distinct parts (van Schalkwyk, 2004; Lettinga and Hulshoff Pol, 1991):

1. A sludge bed at the bottom of the reactor where the heaviest portion of the biomass is situated.
2. A sludge blanket that is situated slightly above the sludge bed and is a diffuse layer of fluidised sludge flocs and small granules.
3. A gas-solid separator at the top of the reactor where the gas is separated from the sludge by means of gas baffles. The sludge particles that have been separated from the gas will settle back on the sludge bed (Stanbury, 2017; van Schalkwyk, 2004).

Wastewater is directed to the bottom of the reactor to ensure uniform distribution (IPPC, 2006). The organic compounds are then metabolised by the anaerobic biomass within the reactor. This leads to the conversion of organic matter into biogas and new biomass (van Schalkwyk, 2004). The biogas is then separated from the sludge, after which the clean effluent is pumped out of the top of the reactor. Typically, the design of the UASB reactor favours the formation of heavy biomass/granules, but simultaneously aims to maximise the hydrolysis of suspended solids. A schematic illustration of a UASB reactor design is shown in Fig. 6.1.

It is possible to change the design of these reactors to suit low to very high hydraulic capacities. Furthermore, they exhibit good flexibility when it comes to treating wastewater with high COD levels (van Schalkwyk, 2004). The success of this system is largely based on two principles. The optimal contact between the sludge and wastewater is acquired by means of natural mixing within the reactor due to biogas production, in addition to a well-designed inlet system that results in the wastewater being equally distributed within the reactor (Stanbury, 2017; van Schalkwyk, 2004). A typical loading rate for this system is about 10 kg $COD.m^{-3}$ per day, with loading rates of up to 60 kg $COD.m^{-3}$ having been reported (IPPC, 2006).

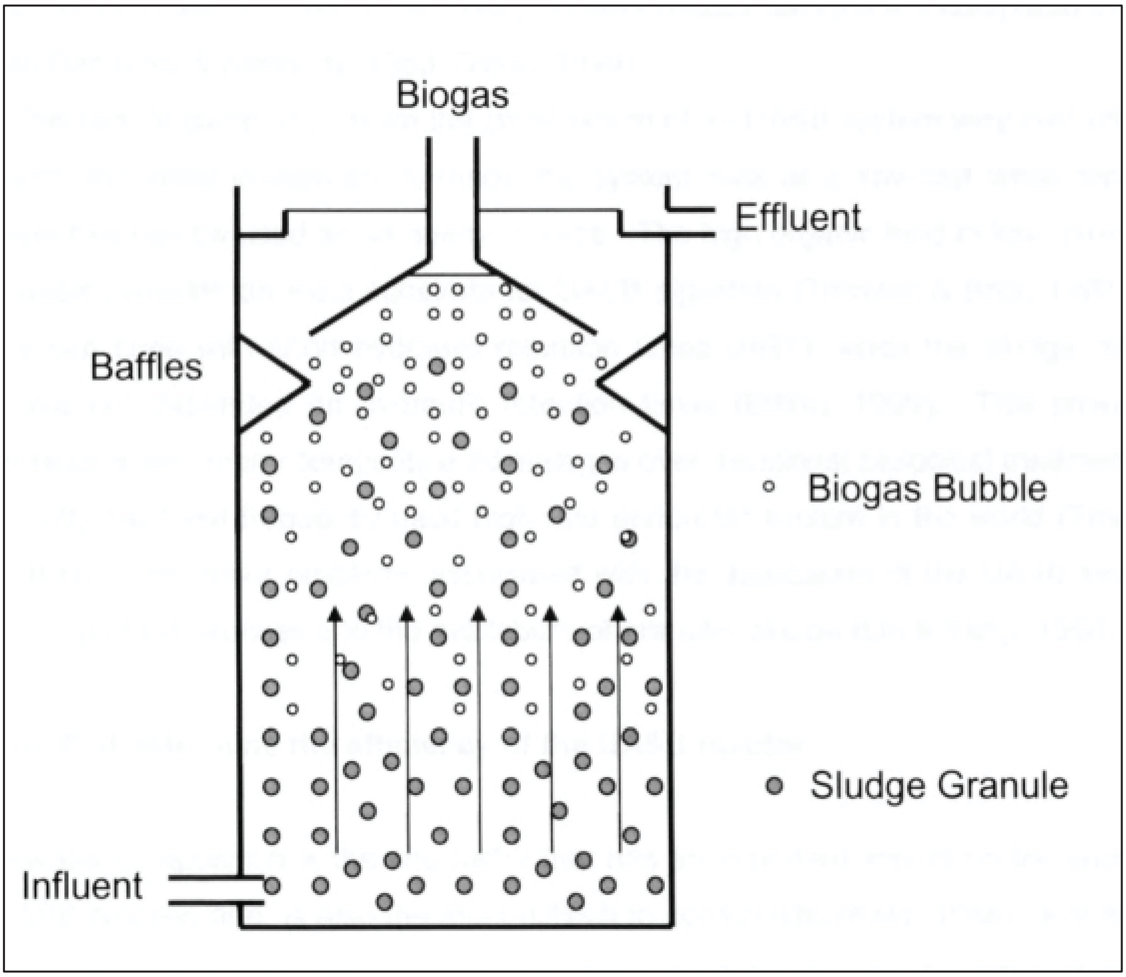

Figure 6.1 Typical upflow anaerobic sludge bed (UASB) reactor (van Schalkwyk, 2004)

Anaerobic sludge blankets are an efficient technique for the treatment of a variety of types of wastewater, including sugar-beet waste, domestic effluents, slaughterhouse waste, and agricultural effluents (Stanbury, 2017), with van Schalkwyk (2004) stating that the high organic load observed in food processing effluents provides an ideal substrate for UASB digestion. Since the sludge retention is not dependent on hydraulic retention times, the reactor is able to accommodate short hydraulic retention time (HRT). In comparison to other 'new' systems, the UASB reactor is relatively simple to operate. It furthermore does not require support media to operate (Stanbury, 2017). These characteristics provide the UASB reactor with various competitive advantages over other traditional biological treatments (van Schalkwyk, 2004).

6.4.3 Tertiary treatment options

Tertiary treatment typically refers to any method which is regarded as a 'polishing' step. Tertiary treatment is the further treatment of wastewater effluent from secondary processes, to remove any suspended, colloidal, and dissolved materials that may remain after processing (Stanbury, 2017; Manivasakam, 2013; IPPC, 2006). These elements may be simple inorganic compounds such as nitrates and metal ions or more complex organic molecules. Constituents of particular concern are ammonia, plant nutrients (nitrogen and phosphorus), dangerous and priority hazardous compounds or residual SS (Stanbury, 2017; IPPC, 2006). When selecting a suitable nutrient control strategy, it is important to consider the following factors (IPPC, 2006):

- The characteristics of the raw wastewater
- The type of WWTP to be utilised
- The required level of nutrient control
- The need for seasonal or year-round nutrient removal

Biological nitrification/denitrification

The IPPC (2006) Directive describes the following four types of denitrification processes:

In **preceding denitrification**, wastewater enters the denitrification basin. Nitrogen in the form of NH_4 does not experience any changes when passing through the basin, whereas organic nitrogen is partially hydrolysed to NH_4. The hydrolysis is completed in the subsequent nitrification basin, and the ammonium gets nitrified to nitrate. The nitrate which is formed passes from the nitrification basin outlet to the denitrification basin, where it can reduce the nitrogen concentration.

In systems using **simultaneous denitrification**, aerobic and anaerobic zones are formed on a targeted basis by controlling the basin's oxygen input. Most simultaneous denitrification basins are designed as circulation basins.

In systems with **intermittent denitrification**, fully stirred and activated sludge basins are periodically aerated. In such a system, aerobic and anaerobic processes take place successively within the same basin. The extent of nitrification and denitrification may be adjusted to suit the feed conditions.

In **cascaded denitrification** systems, multiple basin compartments consisting of aerobic and anaerobic regions are arranged in series without an intermediate sedimentation step. The raw wastewater is passed into the first cascade to ensure that substrate present in the wastewater is optimally utilised.

Generally, these processes provide a high potential for removal efficiency, high operating stability, and reliability. Furthermore, the process is relatively easy to control and does not require a large area of space to be constructed (IPPC, 2006).

Ammonia stripping

In the food, drink and milk sector, it is a common occurrence for condensates to contain high concentrations of ammonium. The ammonium can be stripped from the condensate by utilising a two-step system, which consists of a desorption and an adsorption column. Both columns contain packing material, which increases the water-air interface (Larsen et al., 2013; IPPC, 2006).

The **desorption column** is charged with an alkalized condensate from the top. This leads to the NH_4^+ - NH_3 equilibrium shifting in favour of ammonia (NH_3). Subsequently, NH_3 moves towards the bottom of the column. Air is injected simultaneously at the base of the column. In this counter-current process, NH_3 is transferred from the liquid phase to the gaseous phase (Larsen et al., 2013; IPPC, 2006).

Thereafter the NH_3-enriched air is transferred to the **adsorption column**. Here, the ammonia is removed from the stripping air by means of an acidic solution, which consists of approximately 40% ammonium sulphate being circulated in the desorption column. After the NH_3 has been removed from the air, the clean air may be reused for further stripping (Larsen et al., 2013; IPPC, 2006).

Ammonia levels within wastewater are usually strongly regulated, due to ammonia's toxic effect on the environment. When implementing this process, ammonium concentrations of less than 2 mg/L may be achieved in the outflow, which corresponds to removal efficiency of about 99% (IPPC, 2006). Furthermore, this procedure is a viable option for facilities aiming to be environmentally friendly, since it results in a reduced nitrogen level, creates less waste, and allows for the reuse of water as service water (Larsen et al., 2013; IPPC, 2006).

Biological removal of phosphorus

If facilities within the food, drink and milk sector make use of cleaning agents that contain phosphate, their wastewater may contain significant levels of phosphorus. Up to 25% of the phosphorus found in raw wastewater can be removed by means of primary and secondary treatment. However, should further removal be required, biological methods may be used to achieve this (IPPC, 2006). When applying biological methods, the phosphorus is removed from the effluent, incorporating it into the biomass and wasting the excess phosphorus-laden biomass (WEF, 2015). This process is dependent on specific groups of bacteria that are capable of metabolising phosphorus in excess of their growth requirements when exposed to anoxic conditions in the presence of volatile fatty acids (VFA) and then subjected to aerobic conditions (WEF, 2015). These bacteria are commonly referred to as *polyphosphate-accumulating organisms* (PAOs).

When subjected to anoxic conditions, PAOs take up VFAs from the wastewater and store this carbon within their cells. Once subjected to aerobic conditions, the PAOs can use this carbon reserve for vital functions such as growth, cell maintenance, and creating phosphorus reserves within the cells. The phosphorus acquired from the wastewater is stored within the cells as polyphosphates, which in turn results in the significant increase of phosphorus observed in the sludge (WEF, 2015). Sedimentation is used to separate the PAOs with high phosphate content, along with the biomass from the clean water. These PAOs are then subsequently removed from the system when the excess biomass is removed. The phosphorus-removal efficiencies of various wastewater treatment processes are summarised in Table 6.5.

Table 6.5: Phosphorus removal efficiencies of various wastewater treatment processes (IPPC, 2006)

Treatment Process	Removal of Phosphorus (%)
Primary processes	10–20
Precipitation	70–90
Activated sludge	10–25
Trickling filter	8–12
Biological phosphorus removal	70–90
Carbon adsorption	10–30
Filtration	20–50

Biological phosphorus removal is applicable in any process where wastewater containing phosphorus is produced. Therefore, it is a suitable treatment process for facilities within the fruit and vegetable processing industry.

Dangerous and priority hazardous substances removal

It is not uncommon for organic solvents, pesticide residues, and toxic organic and inorganic chemicals to appear in wastewater streams. The removal of many of these substances may be achieved by implementing treatment processes such as sedimentation, precipitation, filtration, and membrane filtration. However, further removal may be accomplished by utilising processes such as carbon adsorption and chemical oxidation (WEF, 2015; IPPC, 2006).

The ***carbon adsorption*** process utilises granular activated carbon in the form of a filtration bed. The wastewater passes through the filtration bed, where organic molecules are absorbed on the carbon surface (Cheremisinoff, 2016). Once the carbon is saturated with adsorbed molecules, it may be removed from the system and regenerated. Bituminous coal is the carbon source most widely utilised for the process (Cheremisinoff, 2016). Certain organic compounds found in wastewater exhibit resistance to biological degradation and often contribute to the foul odour, taste, or colour of the water. The activated carbon has an affinity for these organic constituents. The adsorption rate of this process is generally influenced by the carbon particle size, but not by the adsorptive capacity (Cheremisinoff, 2016).

Chemical oxidation may be used to remove ammonia, lower the residual organics concentration, and reduce the bacterial and viral content of wastewater. This is accomplished by using oxidative reagents such as chlorine, chlorine dioxide, and ozone (Jafarinejad, 2017; IPPC, 2006).

Filtration

Filtration is often used as a wastewater polishing step, which ensures the removal of solids. However, unlike processes such as sedimentation or DAF, filtration does not require a difference in density between the particles and the liquid (IPPC, 2006). The separation of the particles from the wastewater occurs due to the presence of a pressure gradient following the passage of water through the filter. Thus, the filter medium ensures that the particles are held back (IPPC, 2006).

The type of filter used may vary based on the nature of the solids within the wastewater. Standard sand filters are generally used for the removal of SS, since the soluble BOD levels are usually very low after aerobic treatments (IPPC, 2006). Simple sand filters can remove particles down to 5 μm in size. More complex systems, such as a multi-media filter – which generally consists of discrete layers of sand and anthracite – are able to efficiently remove particles down to 2 μm in size (Mobley, 2001; IPPC, 2006).

Membrane filtration

Membrane filtration systems make use of a pressure-driven, semi-permeable membrane to achieve selective separations (IPPC, 2006). The selectivity of these systems can be attributed to the pore sizes of the membranes. For instance, if the aim of the process is to remove precipitates or suspended solids, relatively large pores may be used, whereas when the aim is to remove inorganic salts or other organic molecules, very small pores are generally used (Manivasakam, 2013; IPPC, 2006). These systems function by allowing the feed solution to flow over the surface of the membrane. The clean water then passes through the membrane while the contaminants and a portion of the feed remain in the solution (IPPC, 2006). The following types of membrane filtration system exist:

- **Crossflow microfiltration (CFM)** is a filtration system that makes use of membranes with pore sizes of approximately 0.1–1.0 μm. This technology is however not regularly implemented in the food processing industry since it is not capable of removing suspended solids. Therefore, it is generally best utilised as a pre-treatment for other filtration methods such as nanofiltration (Manivasakam, 2013; IPPC, 2006).
- **Ultrafiltration (UF)** is a process similar to CFM, however it makes use of smaller pores (0.001–0.02 μ; IPPC, 2006). This smaller pore size allows these systems to reject molecules with a diameter larger than 1 nm or nominal molecular weights larger than 2 000. To prevent the fouling of the membrane, primary treatment is generally required (IPPC, 2006).
- **Reverse osmosis filtration (RO)** may also be referred to as hyperfiltration. This technique can reject dissolved organic and inorganic molecules (Manivasakam, 2013; IPPC, 2006). Wastewater is filtered through a semi-permeable membrane at a pressure greater than the osmotic pressure experienced due to the presence of salts. This allows the clean water to be separated from the dissolved salts (IPPC, 2006). An advantage of RO filtration is the fact that dissolved organics are subjected to a less selective separation procedure than in other methods. RO filtration furthermore yields product streams of high quality, which usually allows the water to be reused within the manufacturing processes (IPPC, 2006). While this method may be highly effective, the

cost of the membrane remains a limiting factor. The membranes need to be replaced at regular intervals because they are susceptible to clogging (Manivasakam, 2013).

- **Nanofiltration (NF)** is a technique that combines features of UF and RO with a high selectivity. This method can remove organic molecules with low molecular weights (200–1 000 g/mol). This may be achieved by utilising membranes that have specifically defined pore sizes; however, their retention is dependent on the electrostatic charges of the molecules that must be separated (Manivasakam, 2013; IPPC, 2006). Furthermore, these systems have a selective permeability for minerals. NF generally operates at moderate pressures – within the range of 1–5 MPa (IPPC, 2006). Due to the lower pressure requirements, nanofiltration is a cost-effective filtration method (Manivasakam, 2013).
- **Electrodialysis** can yield ionic separation by utilising an electric field as its driving force instead of hydraulic pressure (Manivasakam, 2013; IPPC, 2006). These systems make use of membranes that have been modified to be ion selective. A series of specifically modified anion- and cation-permeable membranes are arranged in an alternating order between an anode and a cathode. Membranes typically used for these purposes include cellophane and cellulose nitrate (Manivasakam, 2013). A major drawback of this technique is that the membranes are very susceptible to fouling. However, when subjecting the wastewater to a pre-treatment with activated carbon or chemical precipitation, the clogging of membrane-precipitated salts may be prevented (Manivasakam, 2013; IPPC, 2006).

6.5 TECHNOLOGY ADOPTION

When considering the adoption of wastewater treatment technologies within the FVPI, it is observed that most of the facilities at the very least resort to primary treatment before discharging the wastewater (Table 6.3 and 6.4). However, the secondary and tertiary treatment technologies are adopted to a lesser extent. Based on the data acquired from both a survey and site visits, it appears that around 47% of the facilities make use of secondary wastewater treatment processes, while only 16% of the facilities make use of tertiary treatments. The lack of tertiary treatments is however expected, as it is generally only applied if previous treatments were not sufficient. The adoption of technologies may also be dependent on what is done with the final wastewater effluent. For example, facilities who discharge their effluents into municipal water systems are likely to only apply primary treatments, while those who intend to reuse the water for irrigation or other processes may be more inclined to apply more extensive treatment options. Furthermore, a wide range of adopted technologies are observed, all differing in complexity.

Primary treatment:

Primary treatments are generally rather simplistic techniques, with most facilities focusing on the removal of suspended solids from the effluent. Thus, it is frequently observed that facilities resort to a form of filtration to accomplish this. Most of the facilities investigated make use of screen filters, with one facility using a bag filter. The use of sedimentation tanks was also observed at certain facilities. After sedimentation and removal of solids is accomplished, the pH of the effluent may need to be adjusted. Therefore, a neutralisation step may be required. However, only 47% of the facilities investigated neutralise their effluent. In Table 6.3, it can be seen that industrial unit 3013.1 did not make use of any of the abovementioned technologies, but rather made use a product called Eco-Tabs™. Eco-Tabs™ Wastewater Tablets are solid, sustained-release tablets (Eco-Tabs, 2020). These tablets aim to assist the growth of beneficial aerobic microorganisms, increase settling rates, decrease sludge blankets, reduce corrosive gases, and increase the efficiency of flotation skimmers.

Secondary treatment:

As stated earlier, only 47% of the facilities investigated resorted to secondary effluent treatments. Most of these facilities made use of anaerobic or aerobic lagoons. Both anaerobic and aerobic lagoons have proven to be effective wastewater treatment options. Industrial unit 3013.13 has applied an aerobic lagoon for its wastewater treatment. This option should be suitable for its purposes, since the plant produces 332 294 m^3 of wastewater per annum, with a COD loading of 1,596 mg/L. The aerobic lagoon should be capable of reducing the COD levels to below 100 mg/L. Industrial units 3013.14 and 3013.16 use more complex methods. Industrial unit 3013.14 uses a three-stage bioreactor, which is reportedly capable of reducing its COD levels from 3 000 mg/L to less than 100 mg/L. This facility only produces 60 m^3 of effluent per day, meaning that a large wastewater treatment plant is not required.

Industrial unit 3013.16 uses an upflow anaerobic sludge blanket (UASB) reactor, which is capable of efficiently treating effluents with high COD levels (van Schalkwyk, 2004). The UASB also produces biogas, which may be used to power parts of the facility. This technology is suitable for this specific facility due the fact that it produces large volumes of effluent containing high COD levels. Industrial unit 3013.8, on the other hand, utilises a septic tank and a French drain – which is a rather simplistic method. Although it produces very little effluent (500 m^3 p/a), the effluent contains very high COD levels (23 350 mg/L). It is unlikely that the French drain system would be able to reduce the COD level to an acceptable level before the wastewater is used for irrigation.

Tertiary treatment:

Upon investigation, it can be noticed that very few facilities apply tertiary treatment to their wastewater effluents. This is however not surprising, as tertiary treatments are generally only utilised when the effluents require further treatment. When considering the facilities that make use of tertiary treatments, it is observed that rather basic techniques are applied. Two of the facilities have a filtration step, either passing the effluent through a peat bed or a membrane system. Industrial unit 3013.2, on the other hand, treats the effluent with aluminium sulphate [$Al_2(SO_4)_3$] as well as subjects the wastewater to chlorination. The lack of facilities applying tertiary treatments could be explained by the fact that their primary and secondary treatments may be effective enough to meet their predetermined targets. In addition, facilities that discharge their effluents into municipal wastewater treatment plants do not require their effluent to be treated as extensively before being discharged.

6.6 WASTEWATER TREATMENT PRACTICES AT THE FRUIT AND VEGETABLE PROCESSING INDUSTRIES VISITED

6.6.1 Description of treatment practices

Industrial unit 3013.1 is located in Limpopo and is involved in the juicing of citrus fruits, with grapefruit and oranges being the main varieties. Wastewater treatment industrial unit 3013.1 consists of screen filtering for solids and pH neutralisation. The effluent is then used to irrigate pastures surrounding the facility.

Industrial unit 3013.2 is involved in the processing of fruits, with the tropical varieties being the main inputs. Three different facilities on site manufacture juice concentrates/blends/purees, fruit cubes, individually quick frozen (IQF) fruit pieces, and canned products. Primary wastewater treatment involves the neutralisation of pH, followed by physical screening (after screening, the water is pumped to a holding tank, which has a tap to allow for the water to be used for outside cleaning). The effluent is then pumped to sedimentation tanks and eventually to a dam that serves to further separate the liquid effluent from floating solids. Secondary treatment is accomplished by using anaerobic lagoons that are covered with tarpaulins (Figure 6.4) followed by aerobic lagoons (Figure 6.5). The final effluent is pumped into a holding dam, where it is then used for orchard irrigation.

Figure 6.2: Anaerobic lagoons used at industrial unit 3103.2

Figure 6.1: Aerobic lagoons (with aerator) used at industrial unit 3103.2

Industrial unit 3103.3 is a relatively small facility located in the Cederberg region and is involved in the bottling of jams and other preserves, mainly for the domestic market. The raw materials are mainly of the deciduous variety and include apricots, blueberries, apples, and pears (among others). Wastewater treatment in industrial unit 3013.3 consists of a septic tank with a French drain system leading into a holding tank. The water then runs through a peat filtration system before being pumped into a smaller tank to be used for garden irrigation.

Industrial unit 3013.4 is a potato-processing facility located on the west coast of South Africa. Other vegetables are used in secondary or tertiary processes, but these are usually bought in a pre-processed state. Wastewater treatment in the facility is rudimentary, with sedimentation tanks being used to separate the majority of the solids from the process water. The process water and seawater (used in initial conveying and washing) is then mixed and discharged into the ocean.

Industrial unit 3013.5 is a vegetable processing facility located in Limpopo. Four processing lines are active at the facility, with canned tomatoes, tomato puree, gherkins, and atchar (mango and vegetable varieties) being the main outputs from each, respectively. Wastewater treatment includes the use of settling dams, through which the effluent is directed. Moving screen filters within the same settling dams further separate the solids (Figure 6.6 and Figure 6.7), with the final wastewater then used for irrigation purposes.

Figure 6.3: Inlet to settling dams at industrial unit 3013.5 (angle 1)

Figure 6.4: Settling dams with moving screen filter at industrial unit 3013.5 (angle 2)

Industrial unit 3103.6 is a manufacturer of frozen vegetables products and is located in southern Gauteng. Wastewater treatment before discharge into the municipal system includes screening, lye addition, flocculation treatment, and decanting.

Industrial unit 3103.7 is located in Limpopo and is involved in the production of bottled piquanté peppers, as well as other value-added vegetable products including atchar, salsas, pickles, and sauces.

Production occurs year-round, with a peak between January and June (due to the piquanté season). Effluent treatment consists of screen filtering before discharge into the municipal sewerage system.

Industrial unit 3103.8 is located in the Western Cape and incorporates two separate facilities (eastern and western). The eastern plant is involved in the canning of deciduous fruits, while the western plant is responsible for the production of canned vegetables

Effluent streams (300 000 kL per annum) can be split into lye-peeling wastewater (COD 10 000–15 000 mg/L) and other water (COD 7 000–9 000 mg/L), with the treatment thereof comprising screening for solids followed by aeration before pumping into dams. Effluent is then consistently pumped between dams until a sufficiently low COD has been obtained, after which the water is used for field irrigation of the company farm.

Industrial unit 3013.9 is a dried fruit producer located in the Western Cape. Effluent management involves an initial filtration step by means of a bag filter, after which the effluent is mixed with sewage from the facility and discharged into a three-stage aerobic bioreactor. After this, the treated water is passed through a peat bed for a final filtration step. The treated water is then held in a reservoir, from which it is either discharged into the municipal system or used to irrigate the lawn. The facility reported that the municipality monitors its wastewater quality monthly, routinely checking parameters such as pH, biomass, conductivity, TSS, calcium, chlorine, potassium, and COD. Specific readings were not provided, however. The facility does not have any wastewater quality targets in place other than achieving a COD level of less than 100 mg/L. Its wastewater treatment process was reported to be able to reduce COD levels from above 4 000 mg/L to below 100 mg/L. This means that their treatment process is highly effective. It is, however, important to note that drying facilities rarely produce high volumes of effluent; their effluents generally also do not possess high organic loads.

When questioned about the possibility of further beneficiation of the effluent streams, the facility manager reported that the water could be used for irrigation, but that effluent volumes are too low to fully supply the orchards. Their monthly energy requirement of approximately 140 000 kWh is supplied by the municipal grid as well as a generator on site.

Industrial unit 3013.10 is located in the coastal region of the Eastern Cape and is involved primarily with the freezing of fruit products for niche overseas markets. Limited piquanté pepper canning also takes place on the premises. Industrial unit 3013.10 estimates that effluent volume is approximately 80% of its incoming water, with the sole treatment thereof being the screen filtering of solids before discharge into the municipal system.

Industrial unit 3013.11 is an apple-juicing facility located in the Southern Cape. The facility generates a daily effluent volume of 60 m^3 of water, which is passed through screens to remove solids – after which lye is added as a neutralisation step. The effluent is also subjected to a caustic recovery process. Thereafter the water is pumped to a UASB reactor which is situated about 2 km from the factory. Thereafter the water is pumped to a settling dam, from which it is used to irrigate the orchards. In 2020 the facility installed an anaerobic digester to treat their solid organic waste. This anaerobic digester requires water to operate, thus the facility uses the effluent generated after the caustic recovery process. For this to happen, the effluent is passed through the digester before being pumped to the UASB reactor. This treatment process can yield COD levels of between 6 000 and 8 000 mg/L, with a pH level of 6.31. Their pH, COD, TSS, and Na-absorbance is monitored monthly by the CSIR. No further beneficiation for the wastewater effluent was reported. They do, however, view their solid waste as a source of income. After the waste is passed through the digester, it can be sold off as a soil enhancer or animal feed (depending on the type of material digested).

The facility's annual energy requirement of 3 500 000 kWh is supplied by means of a 16-ton coal boiler, an eight-ton coal boiler, a 1.4 ton biogas boiler, the municipal grid as well as a 350kW solar system (provides 1/3 of the daily requirement).

Industrial unit 3013.12 was up until 2007/2008 involved with pineapple canning. With the unprofitable nature of canning industry, the decision was reached to retrofit the factory into a juicing operation Effluent treatments include the filtering of large solids using a screen filter (Figure 5.12) and pH buffering (most often the addition of lye). Solid waste is sold to local farmers as animal feed.

Industrial unit 3013.13 is located in the Eastern Cape and is involved in the canning and bottling of

Figure 6.8: Screen filter used in industrial unit 3013.12 (prior to neutralisation treatment)

various members of the *Capsicum* (pepper) family. Typical products include the red cherry pepper, sweetheart pepper, and jalapeño. No effluent treatment is applied at industrial unit 3013.13. Catch pots are however used to reduce the number of large solids entering the municipal system.

Industrial unit 3013.14 is located in the Eastern Cape and is involved in the juicing of citrus for concentrate production. Effluent treatment at industrial unit 3013.14 consists of static screens to remove the solids, followed by pH buffering by means of lime addition. The wastewater is then decanted, after which it is split into two separate streams. Half of the wastewater is treated by means of an oxidation ditch, after which it is directed to a clarifier where additional solids are allowed to settle. The other 50% of the wastewater is directed through a trail system consisting of an aerobic and anaerobic reactor arranged in series. A membrane system removes any additional solids. Both the effluent streams are used for the irrigation of pastures following treatment.

Industrial unit 3013.15 is a juicing and packaging facility located in the Boland region of the Western Cape. Their production period runs from October through to April. The facility produces 3 000–4 000 kL effluent per month. All the effluent is collected in a pit, from which it is passed through a screen to remove solids. Then the effluent is pumped to a 60 000 L tank where it is mixed to ensure a consistent flow. The effluent is also treated with caustic to neutralise the pH. Bio-Tabs are then added to the effluent to lower the COD levels. After these primary treatments, the effluent is discharged into the municipal system. The facility reports that it aims to keep their COD levels below 5 000 mg/L (with varying success). The company has a total energy requirement of 400 000 kWh per annum, which is supplied by two steam boilers, solar panels, and the municipal grid.

The facility reports that in their view there is no further beneficiation of their effluent streams or solid waste outputs. This is mainly because the facility does not have orchards close by; irrigation is thus not an option. Furthermore, the tariffs for incoming and outgoing water are relatively cheap; there is thus no need for the facility to spend large amounts of money on building an advanced wastewater treatment plant.

Table 6.6: Wastewater treatment from survey responses

Industrial unit	Annual effluent volume (m^3)	Effluent treatment
3013.1	130 000	***Primary treatment*** Treatment with Eco-Tabs™ * ***Secondary treatment*** None ***Tertiary treatment*** None
3013.2	415 000	***Primary treatment*** Filtration for solids removal ***Secondary treatment*** Aerobic and anaerobic bacterial reaction (*undefined*) ***Tertiary treatment*** Chlorination and treatment with aluminium sulphate [$Al_2(SO_4)_3$]
3013.3	96 000	***Primary treatment*** Filtration for large and fine solids removal Neutralisation ***Secondary treatment*** Aerobic treatment (*undefined*) ***Tertiary treatment***

		None
3013.4	No data provided	***Primary treatment*** Filtration for large and fine solids removal Neutralisation ***Secondary treatment*** Biological treatment (*undefined*) ***Tertiary treatment*** None
3013.5	14 040	***Primary treatment*** Filtration for large and fine solids removal; neutralisation ***Secondary treatment*** None ***Tertiary treatment*** None

Table 6.7: Wastewater treatments and disposal routes at visited facilities

Facility	Treatment description	Method of disposal
3013.6	***Primary treatment*** Screen filter for solids removal Neutralisation	Irrigation
3013.7	***Primary treatment*** Screen filter for solids removal Neutralisation Sedimentation ***Secondary Treatment*** Anaerobic lagoons Aerobic lagoons	Irrigation
3013.8	***Primary Treatment*** None ***Secondary Treatment*** Septic tank with French drain	Irrigation
3013.9	***Primary treatment*** Sedimentation tanks and large solids screen	Discharge into seawater
3013.10	***Primary treatment*** Settling dams Screen filter for solids removal	Irrigation

3013.11	***Primary treatment*** Screening filter for solids removal Neutralisation via lye addition Flocculation and sedimentation	Municipal waterworks
3013.12	***Primary treatment*** Screen Filter	Municipal
3013.13	***Primary treatment*** Screen filter for solids removal ***Secondary treatment*** Aerobic lagoons	Irrigation
3013.14	***Primary treatment*** Bag filter ***Secondary treatment*** Three-stage aerobic bioreactor ***Tertiary treatment*** Filtering through peat bed	Irrigation
3013.15	***Primary treatment*** Screen filter for solids removal	Municipal waterworks
3013.16	***Primary treatment*** Screening filter for solids removal Neutralisation ***Secondary treatment*** UASB reactor and settling dam	Irrigation
3013.17	***Primary treatment*** Screening filter for solids removal Neutralisation	Municipal waterworks
3013.18	***No treatment applied***	Municipal water works
3013.19	***Primary treatment*** Static screen Neutralisation Sedimentation ***Secondary treatment*** Anaerobic and aerobic batch process arranged in series ***Tertiary treatment*** Membrane process	Irrigation

6.6.2 Interesting cases

Industrial unit 3013.14 is a dried-fruit producer located in the Western Cape. They are a relatively small facility, employing 130 permanent staff, with the year-round supply of raw inputs (dried tree fruit from a variety of sources) ensuring no seasonality in employment. The company produces approximately 1 000 tons of dried fruit per annum. Considering that national dried tree fruit production was 6 181 tons (2017), 3 013.8 represents approximately 16% of this. The daily water requirements of 60 m^3 are supplied by a 60 m^3/hour borehole, which is treated for high iron and manganese content before use in the plant. The borehole was reportedly installed due to the municipal tariffs placed on incoming water becoming too expensive. The facility's main water-using processes are washing, processing, and facility cleaning.

Naturally drying facilities do not generate large volumes of effluent. In this case the facility reported that they generate a daily effluent volume of 60 m^3 . It is however important to note that they mix the effluent acquired from the production process with their domestic effluent stream. Whilst the facility does not produce large volumes of wastewater effluents, the facility remains one of the few facilities investigated that applies a primary, secondary and tertiary treatment before discharging the wastewater.

Their effluent management involves an initial filtration step by means of a bag filter, after which the effluent is mixed with sewage from the facility and discharged into a three-stage aerobic bioreactor. After this the treated water is passed through a peat bed for a final filtration step. The treated water is then held in a reservoir, from which it is either discharged into the municipal system or used to water the lawn. The facility reported that the municipality monitors their wastewater quality monthly. They routinely check parameters such as pH, biomass, conductivity, TSS, Ca, Cl, potassium, and COD. Specific readings were, however, not provided. The facility does not have any wastewater quality targets in place, other than achieving a COD level of less than 100 mg/L. Their wastewater treatment process is reportedly able to reduce their COD levels from above 4 000 mg/L to below 100 mg/L. This means that their treatment process is highly effective. It is, however, important to note that naturally drying facilities rarely produce high volumes of effluent; their effluents generally also do not possess high organic loads.

When questioned about the possibility of further beneficiation of the effluent streams, the facility manager reported that the water could be used for irrigation, but their effluent volumes are too low to fully supply the orchards.

Industrial unit 3013.16 is another interesting case, as the research team was able to visit the facility twice, with notable differences in the processes between the visits being observed. Industrial unit 3013.16 is an apple-juicing facility located in the Southern Cape. The facility employs 100 permanent staff and does not rely on seasonal employment, due to the highly mechanised process involved. Production runs from January through to July, with a variety of different cultivars being juiced. The major changes observed were the utilisation of a borehole instead of the municipal supply, a drastic decrease in effluent volume, and a decrease in recorded COD levels.

Total raw material consumption at the facility totals approximately 65 000 tons, which is used to produce approximately 8 000 000 L of concentrate. By improving their production process, the facility was able to lower their water consumption of 300 000 m^3 (2018) to 200 000 m^3 (2020). This is now also supplied by a borehole instead of municipal supply. This changed because the unit cost of water increased from R11/kL to R56/kL. The incoming water is treated for iron and *E. coli*. The facility's main water-using operations are material washing and facility cleaning. The facility is fortunate in that for most of the season it is self-sufficient in terms of process water, with the condensate being reused for most of the processing requirements. The major users of fresh water are the cleaning and material washing operations. Water minimisation was indicated as a focus area for the facility, evidenced by the planned installation of a UV filtration system in the initial washing area. By treating the washing water with the UV system, it is hoped that longer periods between wash water changeover can achieved. A major advantage of the concentration process is the ability to collect and reuse the condensate as process water. Timely maintenance of leaks is also practiced, as well as separation of cleaning chemicals from wastewater for reuse.

As stated earlier, the facility made various changes to their production process. One of their main focuses was reducing their water consumption as well as improving their water-recovery processes. The facility no longer uses any cooling systems, as these were too water intensive; they also no longer use activated carbon to clean their juice. Instead, an absorber is used for this purpose. They are now able to achieve 80% condensate recovery. The facility further reports that all process water is recovered and that they experience minimal water loss. The effluent is subjected to a 10 000 L/h caustic recovery system, which could be improved to 20 000 L/h. The implementation of the caustic recovery system has resulted in a 50% reduction in water use. The caustic that is recovered is reused in the production process. Retentate was initially used to clean their membrane filters, however once it gets into the effluent streams it drastically lowers the effectiveness of the treatment process. For this reason, they have stopped using retentate.

The facility generates a daily effluent volume of 60 m^3 of water. The effluent is passed through screens to remove solids, after which lye is added as a neutralisation step. The effluent is also subjected to a caustic recovery process. Thereafter, the water is pumped to a UASB reactor which is situated about 2 km from the factory. Then, the water is pumped to settling dam, from which it is used to irrigate the orchards. In 2020, the facility installed an anaerobic digester to treat their solid organic waste. This was installed because a regulation change is expected for 2024 that would mean that landfills would no longer be able to accept organic waste. This anaerobic digester requires water to operate, thus the facility uses the effluent generated after the caustic recovery process. To do so, the effluent is passed through the digester before being pumped to the UASB reactor.

The facility reported that they were able to achieve COD levels of 13 296 mg/L when treating the wastewater effluent with the UASB reactor. This remains quite high for treated effluent, but, as mentioned earlier, the facility was using retentate to clean their membrane filters. This resulted in complications being observed during the treatment process. After installing the anaerobic digester, the facility has been able to achieve COD levels of between 6 000 and 8 000 mg/L and a pH level of 6.31. This, however, remains higher than the standard reported for fruit juicing in literature. The facility further stated that it was possible for them to reduce their COD levels to below 6 000 mg/L, however they feel they would then need to install a system that requires less maintenance.

It is, however, important to note that the UASB reactor has barely been operational over the past two years. This is due to various reasons, including high maintenance costs and requiring personnel to supervise the operation. This facility also attempted to install a nano-bubbler as a treatment process, however, this was ultimately deemed unsuccessful. The facility also considered shutting down the UASB reactor due to the high costs related to its operations. Taking this into account, it can be concluded that the anaerobic digester is currently the main secondary treatment applied to the effluent. The facility also reported that the digester was able to yield far better COD levels than they were able to accomplish while using the UASB reactor, which is a much more advanced process. Their pH, COD, TSS, and Na-absorbance is monitored monthly by the CSIR.

No further beneficiation for the wastewater effluent was reported. They do, however, view their solid waste as a source of income. After the waste is passed through the digester it can be sold off as a soil enhancer or animal feed (depending on the type of material digested).

6.7 COMPARISON OF TECHNOLOGIES ADOPTED PRESENTLY AND TECHNOLOGIES ADOPTED IN 1987

As stated earlier, this study serves as an update to a similar study conducted during the 1980s, due the fact that the technology reported in that study may now be outdated or obsolete. After investigating the NATSURV 14 report published in 1987, it has been found that wastewater treatment methods applied in the 1980s were rather simplistic in both aim and the technologies utilised. The main aim of the methods reported in these documents were merely to remove solids from effluent streams. The main methods proposed to accomplish these aims included the segregation of solids and effluent streams, membrane filtration, batch settlers, and dissolved air flotation (Binnie and Partners, 1987). Unfortunately, they do not make any mention of the effectiveness of these methods and what the quality of the final effluent is.

After a comprehensive literature study, as well as investigating the current status of water and wastewater management in the fruit and vegetable processing industry by means of a survey and site visits, it was found that a number of treatment options (varying in complexity) exist. These methods and their effectiveness have already been discussed above. Currently available wastewater treatment technologies are far more expansive and advanced than those used in the 1980s. It is however important to note that not all treatment methods implemented in industry are advanced. It is possible to implement rather simplistic techniques and achieve an effective treatment.

The survey of effluent streams generated in the FVPI sector found that average volumes of 298 m^3/d were discharged from canning processes, 274 m^3/d from juicing processes, 595 m^3/d from freezing processes, and an average of 407 m^3/d for the industry as a whole. Energy-use figures in the industry were more difficult to obtained, but ranged from around 2 780 to 14 000 kWh/d.

6.8 MUNICIPALITIES WHERE INDUSTRIES THAT WERE VISITED ARE LOCATED

The sections below highlight the current municipal by-laws for industrial effluent discharge (which includes water quality requirements and permit requirements for discharge into the municipal sewerage system) and the current water consumption tariffs for 12 municipalities. The municipalities presented in this document are Ba-Phalaborwa, Bergrivier, Buffalo City, Cederberg, Ekurhuleni, Greater Tzaneen, Langeberg, Maruleng, Nelson Mandela Bay, Nkomazi, Theewaterskloof, and Witzenberg. The information presented in this document will form part of the NATSURV of water and wastewater management in South Africa’s FVPI.

6.8.1 Water-consumption tariffs

Most of the municipalities have a fixed monthly charge tariff together with a volumetric water tariff. Municipalities such as Bergrivier, Ekurhuleni, Greater Tzaneen, Theewaterskloof, and Witzenberg have a stepped tariff based on a business’s monthly consumption. Table 6.8 represents the latest volumetric tariffs for the municipalities.

Table 6.8: Latest volumetric water tariffs[1]

Municipality	Consumptive Tariff (ZAR / kL)	
Phalaborwa	14.59	
Bergrivier	0 to 6 kL/month	7.58
	7 to 20 kL/month	15.28
	21 to 50 kL/month	15.28
	51 to 100 kL/month	17.60
	101 to 200 kL/month	18.50
	201 to 1 000 kL/month	19.46
	1 001 to 1 500 kL/month	16.53
	1 501 to 2 000 kL/month	14.03
	More than 2 000 kL/month	11.89
Buffalo City	25.09	
Cederberg	15.37	
Ekurhuleni	0 to 5 000 kL/month	25.37
	5 001 to 25 000 kL/month	25.77
	25 001 or more kL/month	26.89
Greater Tzaneen	0 to 50 kL/month	2.85
	51 to 100 kL/month	4.75
	More than 101 kL/month	5.72
Langeberg	7.96	
Maruleng	13.70	
Nelson Mandela Bay	18.56	
Nkomazi	14.16	

[1] All the tariffs include VAT and are for the period 2019–2020, except Greater Tzaneen and Maruleng, which are for the period 2018–2019.

Theewaterskloof	0 to 30 kL/month	22.00
	31 to 40 kL/month	29.90
	More than 40 kL/month	43.90
Witzenberg	**Block B (aimed at larger commercial and smaller industrial clients)**	
	0 to 300 kL/month	10.14
	301 to 1 000 kL/month	10.14
	1 001 to 8 000 kL/month	10.08
	Above 8 000 kL/month	10.08
	Block C (aimed at larger industrial clients)	
	Above 20 000 kL/month	3.20

6.8.2 Effluent discharge tariffs and policies

All of the municipalities require that any industry or business wishing to discharge trade effluent into the sewerage system applies for an effluent discharge permit and makes sure that its effluent parameters do not exceed those stipulated by regulations. The following sections explore in detail the current effluent discharge costs and regulations in place for each of the municipalities as presented in the water by-laws and tariff documents.

a. Ba-Phalaborwa

For industrial effluent charges, the Ba-Phalaborwa Municipality stipulates that industries and public works pay a charge of ZAR 601 per month, regardless of the volume discharged, as long as the effluent parameters are within the regulated limits. According to its by-law, the maximum permissible COD before discharge is 5 000 mg/L and all sugars and starch should be below 1 500 mg/L.

b. Bergrivier

Bergrivier has a general formula for calculating the tariff associated with the discharge of effluent (presented below). The water by-law does not include the formula for surcharge costs; however, it stipulates industries should comply with the maximum allowable discharge standards.

$$Tc = Qct\left[a\left\{\frac{CODc - CODd}{CODd}\right\} + b\left\{\frac{Pc - Pd}{Pd}\right\} + c\left\{\frac{Nc - Nd}{Nd}\right\}\right]$$

where

Tc = Extraordinary treatment cost to consumer

Qc = Wastewater volume discharged by consumer in kL

t = Unit treatment cost of wastewater in R/kl

CODc = Total COD of wastewater discharged consumer in milligrams/litre (inclusive of both the biodegradable and non-biodegradable portion of the COD)

CODd = Total COD of domestic wastewater in milligrams per litre

Pc = Orthophosphate concentration of wastewater discharged by consumer in milligrams of phosphorus per litre

Pd = Orthophosphate concentration of domestic in milligrams of phosphorus per litre

Nc = Ammonia concentration of wastewater discharged by consumer in milligrams of nitrogen per litre

Nd = Ammonia concentration of domestic wastewater in milligrams of nitrogen per litre

a = Portion of the costs directly related to COD

b = Portion of the costs directly related to the removal of phosphates

c = Portion of the costs directly related to the removal of nitrates

Table 6.9: Numeric values in the Bergrivier industrial effluent formula

Terms	Value
T	ZAR 0.82 / kL
CODd	600 mg/L
Pd	10 mg/L
Nd	25 mg/L
a	0.6
b	0.25
c	0.15

c. Buffalo City

The effluent discharge costs or surcharge costs are not included in the municipality's water by-laws or water and sanitation tariff structure. Table 6.9 highlights some of the maximum allowable concentrations in the effluent. There is no stipulated maximum allowable COD concentration in the by-law.

Table 6.9 Maximum allowable concentrations for effluent discharge in Buffalo City

Parameter	Limit
Total sugar and starch (as sucrose)	1 000 mg/l
Suspended solids	1 500 mg/l

d. Cederberg

The effluent discharge costs or surcharge costs, as well as the maximum allowable effluent discharge concentrations, are not presented in the municipality's water by-laws or water and sanitation tariff structure.

e. Greater Tzaneen Municipality

The effluent discharge costs or surcharge costs are not included in the municipality's water by-laws or water and sanitation tariff structure. Table 6.10 presents some of the maximum allowable concentrations in the effluent. The maximum allowable COD concentration in effluent discharged is not included in the by-law.

Table 6.10: Maximum allowable concentrations for effluent discharge in Greater Tzaneen

General quality limits	Large Works (> 25 Ml/d)	Small Works (<25 Ml/d)
Total sugar and starch (as glucose)	1 000 mg/L	500 mg/L
Suspended solids	2 000 mg/L	1 000 mg/L
Total dissolved solids	1 000 mg/L	500 mg/L

f. Nelson Mandela Bay

Nelson Mandela Bay has a general formula for calculating the tariff associated with the discharge of effluent. The formula is as follows:

Cost of discharge = Discharge Factor X Consumption Volume X Prescribed Tariff

For the 2019/2020 tariffs (including VAT), the discharge factor = 11 kL and the prescribed tariff = ZAR 20.03/kL

In the event that the industries do not comply with the maximum discharge standards, they are liable to a surcharge that is payable to the municipality. The formula is as follows:

$$P = KVT$$

where:

K = effluent discharge factor

V = volume (kL) of effluent discharged

T = prescribed treatment charge, with

$$T = \left(\left\{ Y \left(\frac{CODI - CODd}{CODw} \right) + Z \right\} + \left\{ Y \left(\frac{A_L - B_L}{B_L} \right) \right\} \right)$$

Y = Variable treatment cost per kilolitre = ZAR 2.55/kL (2019/2020; including VAT)

Z = Fixed cost per kilolitre = ZAR 2.47/kL (2019/2020; including VAT)

COD_I = Average COD of the industry measured between 1 April and 31 March annually

COD_W = Average COD of the treatment works (1 000 mg/l)

COD_d = Average COD of Domestic Sewage (400 mg/l)

A_L= Listed parameter exceeding stipulated limit as per the permit and by-law

B_L = Stipulated limit as per the permit and by-law

g. Ekurhuleni

Ekurhuleni has a treatment and conveyance charge for any trade effluent discharged into the sewers, which is an amount calculated on the industrial effluent discharged, the strengths, and the permitted (allowed) concentrations of the industrial effluent discharged during the relevant month. The formula for calculating the treatment cost is presented below. The surcharge costs are not included in the by-law.

$$Ti = \frac{C}{12}\left(\frac{Qi}{Qt}\right)\left[a + b\left(\frac{CODi}{CODt}\right) + d\left(\frac{Pi}{Pt}\right) + e\left(\frac{Ni}{Nt}\right) + f\left(\frac{SSi}{SSt}\right)\right]$$

where

Ti	=	*Charges due per month for the treatment and conveyance of industrial effluent*
C	=	*The C value is a factor in percentage for the full cost of effluent treatment and therefore includes amongst other components, treatment, distribution, admin and resources charges. The percentage adopted is 15% of the sanitation budget.*
Qi	=	*Sewage flow (as defined in the council's wastewater by-laws) originating from the relevant premises in kilolitres per day determined for the relevant month*

Qt	=	*Five-year average of total sewage inflow (as defined in the council's wastewater by-laws) to the council's sewage disposal system in kilolitres per day*
CODi	=	*Average chemical oxygen demand of the sample originating from the relevant premises in milligrams per litre determined for the relevant month*
CODt	=	*Five-year annual average chemical oxygen demand of the sewage in the total inflow to the council's sewage disposal system in milligrams per litre*
Pi	=	*Average orthophosphate concentration originating from the relevant premises in milligrams phosphorus per litre determined for the relevant month*
Pt	=	*Five-year annual average orthophosphate concentration of the sewage in the total inflow to the council's sewage disposal system in milligramsof phosphorus per litre*
Ni	=	*Average ammonia concentration originating from the relevant premises in milligrams o of nitrogen per litre determined for the relevant month*
Nt	=	*Five-year annual average ammonia concentration of the sewage in the total inflow to the council's sewage disposal system in milligrams of nitrogen per litre*
SSi	=	*Average suspended solids concentration originating from the relevant premises in milligrams per litre determined for the relevant month*
SSt	=	*Five-year annual average suspended solids concentration of the sewage in the total inflow to the council's sewage disposal system in milligrams per litre*
a	=	*Portion of the fixed cost of treatment and conveyance*
b	=	*Portion of the costs directly related to the removal of chemical oxygen demand*
d	=	*Portion of costs directly related to the removal of phosphates*
e	=	*Portion of the costs directly related to the removal of ammonia*
f	=	*Portion of the costs directly related to the removal of suspended solids*

For calculation of the treatment charges according to the above formula, the following system values apply:

Table 6.11: Numeric values in the Ekurhuleni industrial effluent formula

	2019/20 Determined factors
Qt	*725 780*
CODt	*722*
Pt	*3.08*
Nt	*23.0*
SSt	*216*
-a	*0.29*
-b	*0.26*
-d	*0.16*
-e	*0.15*
-f	*0.14*

h. Langeberg

The effluent discharge costs or surcharge costs as well as the maximum allowable effluent discharge concentrations are not included in the municipality's water by-laws or water and sanitation tariff structure.

i. Maruleng

The effluent discharge costs or surcharge costs as well as the maximum allowable effluent discharge concentrations are not included in the municipality's water by-laws or water and sanitation tariffs.

j. Nkomazi

The effluent discharge costs or surcharge costs as well as the maximum allowable effluent discharge concentrations are not included in the municipality's water by-laws or water and sanitation tariff structure.

k. Theewaterskloof

The effluent discharge costs or surcharge costs are not included in the municipality's water by-laws or water and sanitation tariff structure. The table below highlights some of the maximum allowable concentrations in the effluent. There is no stipulated maximum allowable COD concentration in the by-law.

l. Witzenberg

The effluent discharge costs or surcharge costs are not included in the municipality's water by-laws or water and sanitation tariff structure.

6.9 WASTEWATER TREATMENT CHALLENGES IN THE FRUIT AND VEGETABLE PROCESSING INDUSTRY

Wastewater generated from fruit and vegetable processing is considered to have a polluting potential due to the fact that typically contains high COD and BOD levels (Cooke, 2008). It has been found that wastewater from these industries is extremely high in both COD and Biological Oxygen Demand (BOD), with levels commonly 10–100 times higher than domestic wastewater (IPPC, 2006) The costs of removing this oxygen demand have risen, be it from using an on-site wastewater treatment plant (WWTP) or because of levies when discharging to a public water course (Cooke, 2008). Possible treatment options have already been discussed above. However, the high costs associated with wastewater treatment remains a challenge.

A possible method to overcome this challenge is to investigate the potential wastewater recycling and reuse. This, however, comes with its own problems. One of the major constraints surrounding wastewater recycling and reuse practices is the perception of risk expressed by consumers (Galanakis and Agrafioti, 2019). It appears that the original source of the water and the intended reuse are some of the main factors influencing the public's perception of recycled water alternatives. It has further been suggested that the main barrier is often not the perception of the public, but rather the authorities' perception of the public's concerns (Dolnicar et al., 2011). Galanakis and Agrafiot (2019) further mention that the concept of potable water reuse, for the purpose of drinking, has been proposed in the U.S. since 1962. While most studies focused on the treatment of sewage wastewater, the principles should still apply when considering the reuse of wastewater in the food industry. Thus, in order to make water reconditioning and reuse a viable option, the public and governing authorities need to be provided with scientific data that would address their concerns regarding the safety, environmental, and economic implications of the proposed water-conservation strategies. More efficient water reconditioning and reuse could be very beneficial in a water-scarce country such as South Africa.

Another approach is to improve the efficiency and effectiveness of treatment techniques. Anaerobic processes that produce methane gas as a by-product show great potential as options that would reduce the waste output as well as the water and carbon footprint of the FVPI. Such processes already exist in the form of UASB reactors, however it has been reported that the installation and maintenance costs of these are too high. The process further requires constantly requires trained operators to monitor the system. Thus, there is a need for improvement in these processes.

CHAPTER 7: ENERGY USE AND MANAGEMENT

7.1 IMPROVING ENERGY EFFICIENCY

Within the food processing industry, water is known as a key processing medium throughout the entire production process – both as an ingredient and a production aid. In addition to its high water consumption, the food processing industry is also known for its high consumption of energy (Lee and Okos, 2011). The global food sector is responsible for the consumption of approximately 200 EJ of electricity per year (Ladha-Sabur et al*.,* 2019). Of this 200 EJ, 45% is related to processing and distribution. Due to industry's high consumption of water and energy, Compton et al. (2018) view the food processing industry as one of the most important sectors when it comes to addressing our environmental impact.

Another determining factor that leads companies to consider more energy efficient processes is the fact that consumers are becoming more interested in the environmental impact of the production process (Legorburu and Smith, 2018). As the global population increases, the demand for food increases – meaning that the food processing industry will need to expand in order to meet the demand. This would result in an increase in the amount of water and energy required to complete the production process. Water shortages and increasing costs have led industries globally to investigate processes that are more water and energy efficient (Lee and Okos, 2011). In countries such as South Africa, there is a particular need to identify more water- and energy-efficient processes.

Compton et al. (2018) investigated the energy consumption of the food-processing industry in the Pacific Northwest region of the United States. They reported that the US food processing industry was responsible for consuming approximately 1.2 trillion MJ in energy in 2010. As seen in Figure 7.1, their investigation found that the animal-slaughtering industry was the most energy-intensive industry, while the sugar-processing industry was the least energy intensive. The fruit and vegetable and dairy industries appeared to have similar energy requirements. Compton et al. (2018) further noted that machine-driven processes are responsible for a large share of the energy consumption. Refrigeration systems and process cooling were the second-largest consumers of energy, followed by heating, ventilation, air conditioning (HVAC), and lighting.

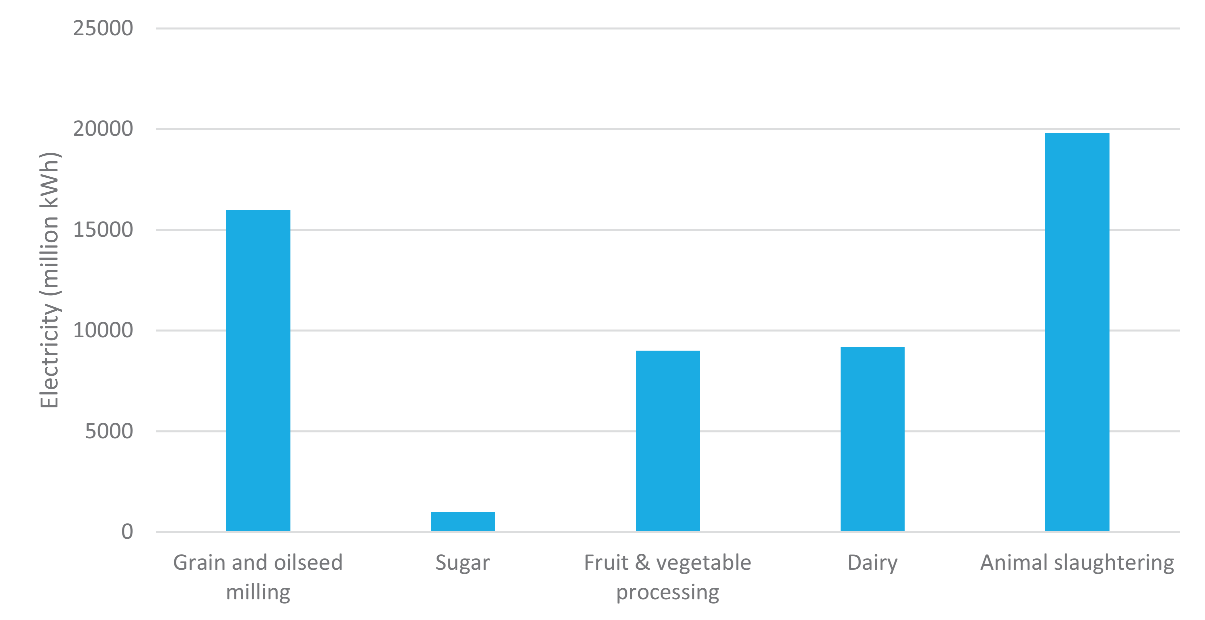

Figure 7.1.: Electricity usage of different sectors within the US food processing industry (Compton et al., 2018)

Energy-consuming processes within the food processing industry may be divided into the following four categories (Compton et al., 2018):

- Process heating and drying
- Refrigeration and cooling
- Mechanical motor-driven processes and equipment used for product handling
- Infrastructure

As shown in Figure 7.2, process heating and refrigeration account for approximately 75% of the total energy consumption in the US food industry. Mechanical equipment such as fans, motors, air compressors, and mixers account for 12%, while the infrastructure consumes 8%. It is not uncommon for heating and refrigeration processes to require large amounts of energy due to the necessity of the facility to meet food safety regulations. Compton et al. (2018) further investigated the elements within machine-driven systems that are responsible for the consumption of energy. Their results are displayed in Figure 7.3.

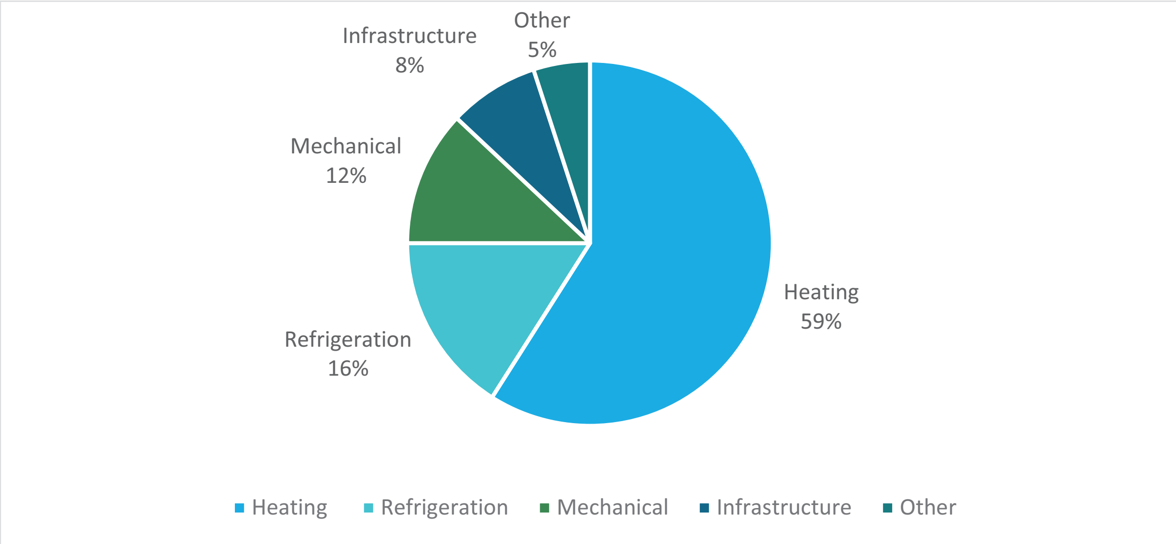

Figure 7.2.: Energy consumption of processes within the US food-processing industry (Compton et al., 2018; Wang, 2014)

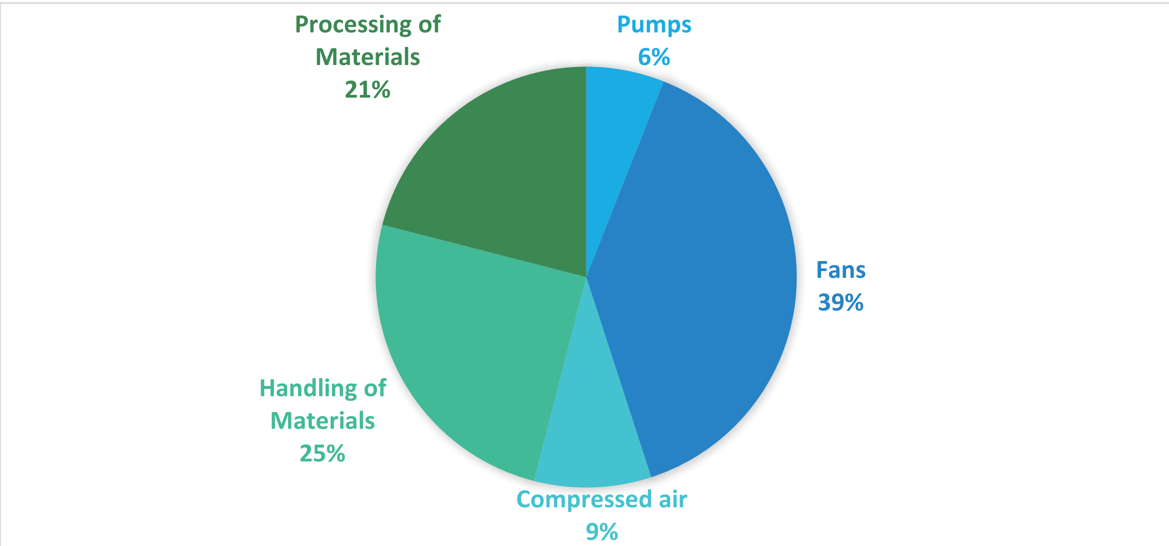

Figure 7.3.: Energy consumption of machine-driven systems in the US food-processing facilities (Compton et al., 2018)

Data on the energy consumption of the FVPI is rather sparse. Most sources only mention the energy consumption of the food processing industry as a whole, but do not report on which processes are specifically energy intensive. However, Masanet et al. (2008) investigated the potential of improving the energy efficiency of the US' FVPI. They reported that the typical uses of electricity in the FVPI are to power conveyors, motors, compressed air systems, and pumps, as well as lighting, heating, ventilation, and air conditioning (HVAC) systems. They further mention that refrigeration is another major consumer of energy in the industry. Masanet et al. (2008) also reported that the frozen fruit and vegetable products were the most energy-intensive processes (Table 7.1). Canning processes are reported to be the second-largest user of electricity, followed by drying and dehydration processes.

Table 7.1.: Consumption of energy in the US fruit and vegetable processing industry (Masanet et al., 2008)

Subindustries	Electricity Usage (TBtu)	Natural Gas Usage (TBtu)	Total (TBtu)	% of Industry Total
Freezing	9.9	21	30.9	31
Canning	8.5	36	44.5	44
Speciality canning	2.1	8	10.1	10
Drying	2.4	13	15.4	15
Industry total	22.9	78	100.9	

Information on the energy consumption of the South African FVPI is even less readily available than that of the global FVPI. However, when considering the studies of Masanet et al. (2008) and Compton et al. (2018), one can assume that the South African FVPI consists of similar energy-intensive processes, albeit with a lower total energy consumption. Therefore, the energy-saving measures applied in the US and UK FVPIs should still be applicable to the South African FVPI.

Energy-saving measures:

Food processing, energy, and water systems are closely interrelated (Savulescu and Kim, 2008) and improving energy efficiency will very likely also lead to reduced water consumption (Savulescu and Kim, 2008; Smith and Kim, 2008). When considering energy saving measures, it is recommended that facilities prioritise energy-saving measures according to their own business strategy and long-term plans (Compton et al., 2018). Compton et al. (2018) further recommend that energy-saving techniques that provide quick and relatively cheap results should be implemented first. An example of this may be the replacement of outdated lights with high-efficiency LED lights. Compton et al. (2018) describe various energy-management programmess that relate to more than 46% of the potential savings. These programmes may be divided into three broad categories: Firstly, plant energy measures, which include basic conservation measures such as preventative maintenance and the training of system operators. Secondly, energy project management, which is a more advanced approach to energy saving; This programme includes the assignment of an energy engineer, identifying and prioritising capital projects as well as the usage of system optimisation tools and practices for key processes. Lastly, integrated plant energy management programmes entail the implementation of an energy-management plan consisting of policies, accountability programs, department- or system-level target goals, and the independent verification of energy savings.

Masanet et al. (2008) provide a complete description of various energy-saving techniques applicable to the FVPI, a summary of which is given in Table 7.2. The processes covered represent those which are determined to be among the most energy intensive within the FVPI (Masanet et al., 2008).

Table 7.2: General energy-saving techniques applicable to the fruit and vegetable processing industry (Masanet et al., 2008)

Process	Energy-saving technique
Blanching	Heat recovery from blancher water or condensate via a heat exchanger
	Upgrading of steam blanchers to modern units with energy-efficient features (e.g. steam seals)
	Heat and hold techniques instead of continuous subjection to heating medium
	Steam recirculation
Dehydration/drying	Use of direct-fired dryers
	Proper and timely maintenance
	Insulation of any hot surfaces on dryer that are exposed to outside air
	Mechanical dewatering of fruit and vegetables prior to drying
	Process control for optimisation of energy inputs
	Using dry air to reduce the amount of energy required to heat and vapourise any incoming moisture
	Heat recovery from product where it is deliberately cooled after drying
Evaporation	Proper and timely maintenance of evaporator
	Use of multiple effect evaporators
	Mechanical or thermal vapour recompression (potentially more effective than multiple effect evaporators)
	Freeze or membrane concentration
Frying	Heat recovery via adsorption cooling
	Heat recovery via exhaust gas combustion
	Using spent fryer oil as fuel
	Heat recovery from fryer exhaust gases
	Heat recovery via adsorption cooling
Pasteurisation and sterilisation	Insulation of all hot surfaces in contact with external air
	Use of helical heat exchangers

	Induction heating of liquids
	Compact immersion tube heat exchangers
Peeling	Heat recovery from discharge steam
	Multi-stage abrasive peeling
	Dry caustic peeling

CHAPTER 8: WATER MINIMISATION AND WATER CONSERVATION IN FRUIT AND VEGETABLE PROCESSING

In this chapter, guidance is provided on measures that could be taken in the water-wise operation of FVPIs. The guidelines and best practices presented here are based on the desk study that was undertaken and valuable information obtained during the site visits and concomitant interviews. It must be emphasised that food health and safety as well as environmental protection are of prime importance and should never be compromised when undertaking any of these measures.

8.1 INTRODUCTION

'Best practice' can be defined as 'strategies, activities or approaches that have been shown through research and evaluation to be effective and/or efficient'. The term is somewhat controversial, because some people feel that there are always ways to improve, and application of the word 'best' suggests that no further innovation is necessary. The European Commission prefers the term 'best available technologies'. Nevertheless, 'best practice' is an accepted term that is widely applied. The catchphrase 'reduce, reuse, recycle' applies to just about all of the world's resources – including water – and forms part of the best-practice hierarchy (Figure 8.1).

Water use, wastewater generation, and cleaner production technologies are inextricably linked and should be considered together by industries seeking to become more sustainable. Reduced water consumption translates into reduced wastewater generation; reductions in chemicals used or the use of less toxic chemicals improves wastewater quality.

Adherence to best-practice technologies can translate into cost savings. However, it is recognised that in some instances, the adoption of best practices may result in inferior products, and a balance needs to be struck between environmental and economic issues.

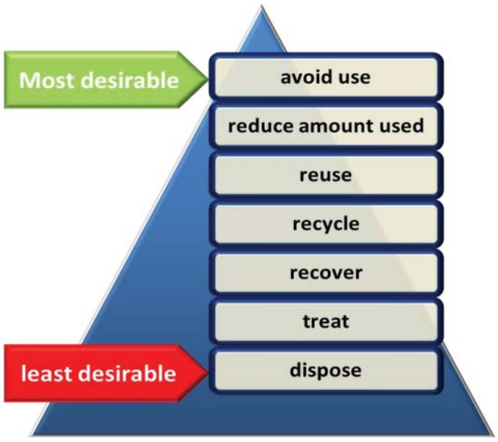

Figure 8.1: Best practice hierarchy – towards a sustainable future

Since the 1980s, the design of systematic methods to reduce water use has received much attention (Kim and Smith, 2008). A systematic approach to the minimisation and prevention of water waste has been described in detail by the IPPC (2006) and consists of the following steps:

1. Obtaining management approval and executing organisation and planning
2. Analysis of the entire production process
3. Assessment of objectives
4. Identification of prevention and minimisation options
5. Carrying out an identification and feasibility study
6. Implementation
7. Continued monitoring and visual inspection

The types of minimisation options under Point 4 (identification of prevention and minimisation options) can be broadly described as three complementary schemes: **water minimisation**, **water reuse/recycling**, and **process changes** (Kim and Smith, 2008). Water minimisation and reuse/recycling are primarily concerned with the design options of the *water networks* present within facilities (Kim and Smith, 2008), while the process changes are primarily concerned with the optimisation of unit operations (Kim and Smith, 2008; IPPC, 2006).

Food processing has its own unique characteristics that make it advisable to start with more simple water-saving measures (e.g. good housekeeping based on efficient management), followed by progression onto more complex methodologies (Klemeš and Perry, 2007). The intermittency of production, as found in fruit and vegetable processing, influences the investment in water and waste minimisation technologies (Klemeš and Perry, 2008) – and a thorough investigation into the economic feasibility would be necessary (Cooke, 2008).

8.2 DESIGN-BASED MINIMISATION

Water pinch is a powerful systematic approach that uses advanced algorithms to identify water-saving opportunities (IPPC, 2006). The technique was developed by Wang and Smith (1994) and is based on the graphical manipulation of limiting water profiles (Klemeš and Perry, 2007). A more detailed description of the concept and its application can be found in Klemeš and Perry (2007), Kim and Smith (2008), and Wang and Smith (1994). The technique has been applied practically by Thevendiraraj et al. (2003). There are a variety of software packages available for water minimisation, which can deal with extremely complex optimisation problems (Smith and Kim, 2008). Panjeshahi et al. (2009) have taken the concept of water pinch further, describing it as 'advanced pinch design' (APD), which combines pinch technology and mathematical programming for a minimum-cost outcome. They also consider the inclusion of ozone treatment in cooling towers for improved recirculated water quality.

8.3 WATER REUSE AND RECYCLING

When freshwater is in limited supply and/or process materials can be recovered, water regeneration is likely to be economically feasible (Smith and Kim, 2008), although treatment for the purposes of water reuse are often not utilised – due to perceived quality concerns (Bromley-Challenor et al., 2013). Also, the fact that water treatment facilities need to be both robust and significant for the achievement of sufficient quality also acts as a deterrent to their implementation (Bromley-Challenor et al., 2013). For the purposes of this literature review, the different methods of wastewater treatment (be it on or off site) will not be expanded on. It is only necessary to appreciate that for the purposes of water recycling/reuse some form of treatment may be necessary. Indeed, 22% of identified water saving opportunities found by Bromley-Challenor et al. (2013) could be attributed to reuse of treated effluent. A description of various wastewater treatments (primary, secondary, and tertiary) can be found in the IPPC Directive (2006). Hamza et al. (2016) have also provided an overview of various anaerobic treatments for high-strength wastewater.

Smith and Kim (2008) divide optimisation strategies using treated wastewater into the following two broad groups:

- **Regeneration reuse**: regenerated water from a WWTP is not supplied to the same operation due to contaminant levels, but may be suitable for use in other operations
- **Regeneration recycling**: water from the WWTP can be fully or partly recycled to the same operation

In addition, Smith and Kim (2008) describe a targeting method for regeneration reuse, but go further in describing how freshwater requirements can be reduced by using the regenerated water in the same operations. If, theoretically, the WWTP was able to supply the same quality of fresh water, a zero discharge of water is possible (Smith and Kim, 2008). The reality, however, is that the treated water is very likely more contaminated than the freshwater. In that case, subsystems requiring better-quality water should only be supplied by fresh sources (Smith and Kim, 2008).

A method for treating minimally contaminated water for the purpose of reuse has been investigated by Mavrov and Bélières (2000), who successfully demonstrated at pilot scale the ability of a three-phase process (pre-treatment, membrane filtration, and UV disinfection) to treat low-contaminant wastewater in an economically feasible manner. The treated water was also found to be suitable for drinking as well as boiler make-up (which has requirements even more stringent than those for drinking water). Wu et al. (2016) have also demonstrated the ability of a relatively inexpensive process (chlorination, bag filtration and activated charcoal filtration) to reclaim water during washing/sorting in an orange canning plant.

In a survey of 18 companies across the food processing industry, the Australian Department of Agriculture (2007) found that the majority of water was used in non-contact processes and therefore concluded that considerable scope exists for the adoption of recycling strategies. Possibilities for water recycling within food processing facilities have also been documented by the California League of Food Processors (CLFP; CLFP, 2015) in its 2014 survey of food processing facilities. Masanet et al. (2008) also make mention of specific water-recycling opportunities available to the FVPI. Recycling/reuse best management practices identified by the CLFP (2015), Masanet et al. (2008), and others include the following:

- Recycling/recirculation to reduce fresh-water requirements (see also Panjeshahi et al. (2009)). Bromley-Challenor et al. (2013) make specific metion of boiler-water reuse.
- Reuse cooling tower overflows for site sanitation
- Reusing process condensate (Amón, Maulhardt, Wong, Kazama, and Simmons, 2015; Bromley-Challenor et al., 2013; Sethu & Viramuthu, 2008; Valta et al., 2017)
- Recirculating seal water
- Phasing out the use of once-through cooling (see also Bromley-Challenor et al., 2013)
- Evaluation of CIP chemicals, timing, and required water
- Reusing process water for irrigation
- Recirculation of water between clustered cooling towers
- Using lye concentrators for lye recovery from process water. This may also assist in the efficiency of UASB (up-flow anaerobic sludge blanket) during wastewater treatment due to improved methanogenesis (Sigge and Britz, 2007).
- Using recaptured wash water as a 'first rinse' for raw fruit entering the washing area. Counter-current washing (washing with progressively cleaner water) is also recommended.

- Sourcing water from incoming raw materials (e.g. tomatoes)
- Segregation of wastewater streams for optimal reuse/recycling
- The use of hydrocyclones for wastewater streams with a high solids content. This allows for increased water reclamation, decreased WWTP costs, and the use of recovered solids as animal feed, mulch, or agricultural additives.

8.4 PROCESS CHANGES AND OTHER WATER OPTIMISATION MEASURES

It is possible to optimise individual processes to further increase water efficiency and minimisation (IPPC, 2006; Smith and Kim, 2008), as examples discussed below show. It is also possible to change product recipes and preservation techniques in order to use less water (Sethu and Viramuthu, 2008).

8.4.1 Reduce driving force for mass transfer

Extraction, absorption, and stripping operations require a driving force for their respective mass transfers, which is very often supplied by water. The driving force, which is obviously linked to the flowrate, can be reduced. It must be noted, however, that a small driving force may result in additional capital requirements and/or the number of stages in the operation (Smith and Kim, 2008).

8.4.2 Water-free operations

Non-water-using operations can replace those using water (Smith and Kim, 2008). Examples of these include the following:

- **Microwave heating and ohmic thawing** in the place of conventional heating techniques such as water baths or steam ovens (IPPC, 2006; Varghese et al., 2014)
- **Alternative separation techniques** such as crystallisation or microwave-assisted extraction that can replace water-driven extraction (Cheng et al., 2011; Smith and Kim, 2008)
- **Dry conveyors** instead of flume systems (Masanet et al., 2008).

8.4.3 Process control and optimisation

Process-control measures can be used to identify any existing spare capacity and avoid any unnecessary water use (Smith and Kim, 2008). The IPPC (2006) gives an extensive list of process-control and optimisation techniques, a summary of which can be found in Table 8.1.

Table 8.1.: Process control for optimal water use (IPPC, 2006)

Technique	Description
Dedicated monitoring and correction of temperature	Reduced water use can also be achieved if the system uses steam for heating
Controlling flow or level using pressure monitoring	Pressure control can be applied using sensors for indirect control of other parameters (e.g. degree of filter clogging). Bromley-Challenor et al. (2013) have shown that water-pressure optimisation may contribute up to 4.5% of total saving opportunities in the UK food and drinks manufacturing sector.
Level measurement	An example of this would be a facility that installed level controls on the supply tanks supplying the flume system for transportation of the material. Previously, an operator would adjust the water supply controls manually, which would enable excessive overflow from the tanks.. Bromley-Challenor et al. (2013) have noted that prevention of overflow can contribute up to 5.5% to identified savings opportunities in manufacturing.
Flow measurement and control	To optimise the use of water, the actual flow rates must be known in the first instance. Many different types of flow meters exist, e.g. rotameters, electromagnetic flow meters, and vortex shedding meters.
Analytical measurement	The use of pH probes can lead to reduced use of acids and alkalis and consequently reduced wastewater generation. Turbidity measurements can be used in the monitoring of process water quality and in the monitoring of CIP systems (to optimize the reuse of cleaning water)
Use of automated stop/start controls	Sensors can detect the presence of raw materials and only supply water when required. Water supplies can be turned off automatically during production stoppages and product change-overs. Bromley-Challenor et al. (2013) have reported that savings from automatic stop controls in the food manufacturing sector may contribute up to 5.9% of identified saving opportunities.
Use of control devices	Valves are the most common control devices and their implementation can reduce water consumption and associated energy requirements
Use of water nozzles	Water consumption and wastewater generation can be reduced by correctly positioning and directing nozzles. Presence-activated sensors and only installing nozzles where required can also ensure that water is only used when and where necessary.
Improved peeling technology	Various peeling techniques for improved water-use/effluent quality can be investigated – such as dry peeling instead of conventional practices (Masanet et al., 2008).

8.4.4 Avoid once-through use

Water is widely used in the food industry as a conduit for cooling or heating, and the use of once-through systems require especially large water volumes (Smith and Kim, 2008). The CLFP (2015) makes specific mention of the fact that 'once-through' cooling should be avoided. In fact, Binnie and Partners (1987) make specific mention of a freezing facility where the use of a once-through cooling system drastically altered the national average specific water intake (NASWI) for freezing in general. It is now a common industrial practice to use recirculating cooling water systems coupled to a heat exchanger (for energy recovery) for reuse and recycling (Smith and Kim, 2008; Panjeshahi et al*.,* 2009). As an example, closed-circuit cooling may result in water savings of up to 80% when compared to an open system (IPPC, 2006). Bromley-Challenor et al*.* (2013) have also noted that 25% of identified savings opportunities may come from the elimination of once-through cooling systems in the UK food and drinks industry. A problem that must be addressed, however, is that of bacterial or algal growth in the closed system (IPPC, 2006). Chemical addition may suffice for the most part, although special attention must be paid to the avoidance of conditions suitable for the proliferation of *Legionella* (Castor et al., 2005; Cooke, 2008; IPPC, 2006).

8.4.5 Improve production scheduling

Product changeover can be reduced in multi-product batch systems to ensure that less water is used for washing (Smith and Kim, 2008)

8.4.6 Improve equipment design

The careful design of equipment can lead to a reduction in solid, liquid, and gas emissions (IPPC, 2006), as well as a reduction in total inherent water use (Smith and Kim, 2008). Examples include the following (IPPC, 2006):

1. Identifying and marking all valves and settings for equipment. This may reduce the risk of staff incorrectly adjusting them.
2. Optimising pipework systems and equipment capacity
3. Designing equipment that is easy to clean

8.4.7 Improve energy efficiency

In the food processing industry, energy and water systems are closely related (Savulescu and Kim, 2008) and improving energy efficiency will very likely also lead to reduced water consumption (Savulescu and Kim, 2008; Smith and Kim, 2008). Masanet et al*.* (2008) provide a complete description of various energy-saving techniques applicable to the FVPI, a summary of which is given in Table 8.2. The processes covered represent those which are determined to be amongst the most energy-intensive within the FVPI (Masanet et al., 2008).

8.4.8 Provide training

Providing staff (at all levels of the company hierarchy) with the necessary training in their duties can minimise consumption and emission levels (CLFP, 2015; IPPC, 2006). The training can be in-house or external and should cover routine operations, the start-up, the shutdown, cleaning, maintenance, abnormal conditions, and non-routine work (IPPC, 2006). The Australian Department of Agriculture (2007) also makes note of the fact that 'behavioural change' may result in water savings of up to 25%, depending on the type of processing facility.

8.4.9 Ensure proper maintenance

Effective planned maintenance can minimise water use and liquid emissions (IPPC, 2006). An example would be that of tanks, pumping equipment, compressor seals, valves, and process drains that can be a major source of leaks and therefore require pre-emptive and timely maintenance (IPPC, 2006; CLFP, 2015). Bromley-Challenor et al. (2013) have shown that fixing supply leaks (in combination with water-balance monitoring) may contribute to 12% of water-saving opportunities in the UK food and beverage manufacturing sector.

8.4.10 Improve cleaning techniques

The IPPC (2006) and Masanet et al. (2008) describe a wide variety of water-friendly cleaning methods. A brief description of these techniques can be found in Table 8.2.

Table 8.2.: Description of BAT cleaning techniques (IPPC, 2006; Masanet et al., 2008)

Type of cleaning practice	Description
Catchpots over floor drains	Fine mesh baskets placed over floor drains to prevent solids from entering the drainage system and consequently the WWTP
Floor and equipment pre-soaking	Pre-soaking the floors to loosen dirt can make subsequent cleaning easier. Depending on the situation, the consumption of water and chemicals may be reduced.
Pigging	'Pigging' is a practice whereby food-grade rubber 'pigs'/projectiles are forced through piping by compressed air to remove excess product between batches. Pigging increases product recovery, decreases water use and wastewater generation, and results in a less contaminated wastewater stream.
Flushing of pipework with compressed air	Gas flushing is effective for removing residual materials from piping and can reduce water consumption in cleaning.
Management of energy, water, and detergents	By conducting trials and recording daily hygiene measurements, it is possible to ascertain a minimum combination of water, energy, and detergents that do not compromise food safety
Hand-operated triggers on hoses	Hoses can be fitted with trigger-control shut-offs or with automatic shut-off valves
Pressure cleaning	High-pressure cleaning can be achieved in a variety of ways and achieves greater cleaning efficacy with the use of less water. It has also been recommended as BMP by the CLFP (2015). Care must however be taken during this operation, especially in confined spaces, due to possible risk of *Legionella* contraction (Castor et al., 2005).
Optimal use of CIP (cleaning-in-place)	CIP systems are cleaning systems incorporated into the equipment (usually during the design stage) and are calibrated in such a way as to optimise the use of water and detergents. The CLFP (2015) also recommends investigating optimal CIP timing and chemical use.
HPLV sprays for cleaning of vehicles	HPLV (high-pressure, low-volume) sprays can be applied to all facilities where materials are delivered by truck
Cleaning equipment immediately after use	Postponing cleaning can result in product residues becoming dry and crusty, meaning more water is needed to remove it

8.5 USE OF NOVEL TECHNOLOGIES

There has been a great amount of interest (propagated by consumer demand and regulatory pressures) in the use of novel processing techniques that could overcome the water and energy deficiencies of conventional practices (Pan et al., 2015; Thirumdas et al., 2015; Toepfl et al., 2006). In a survey by Jermann et al. (2015), 61% of respondents indicated that 'solving environmental or waste issues' was one of the key drivers in the commercialisation of new food-processing technologies, while 79% of respondents indicated that cost saving in terms of water and energy was also a driver. Alternatives to conventional processing may result in less water use, reduced wastewater output, less reliance on fossil fuels, and reduced production of hazardous substances (Chemat et al., 2017). Ultrasound-assisted processing (UAP), ohmic heating (OH), supercritical fluids (SCF), microwave processing, controlled pressure drop process (DIC), cold plasma, high-pressure processing (HPP), and pulsed electric fields (PEF) are examples of such processes (Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Chemat et al., 2017; Thirumdas et al., 2015). Despite large advancements having been made in these novel techniques, more research is required to prove their feasibility in commercial operations. (Jermann et al., 2015). Some limitations experienced by these technologies include high investment costs, a lack of regulatory approval, and incomplete control of variables associated with the operations (Jermann et al., 2015).

Instant controlled pressure-drop technology

'Détente Instantanée Contrôlée' (DIC), which is French for instant controlled pressure drop, is based mainly on the thermodynamics of instantaneity and auto-vapourisation and has been discussed by Chemat et al., (2017) as a 'green' technology. The process has been found to be effective in the microbial sanitization of foodstuffs (even when the microorganisms are in spore form) and has also demonstrated its abilities in vegetable-based extraction processes (Chemat et al., 2017). As a drying technique, it has been found to be useful in the texturing of dried fruit, vegetables, and seaweeds, as well as in the creation of large granule powders – with quality attributes higher than those of traditionally dried or spray dried powders (Michailidis and Krokida, 2015). The advantages include reduced energy requirements and production costs as well as improved quality and safety attributes (Michailidis and Krokida, 2015).

Ultrasound-assisted processing

Power ultrasound (20–100 kHz) finds its mechanism in the cavitation phenomenon in liquid systems. Ultrasound is propagated by a series rarefaction and compression waves in the medium, which at sufficiently high power may be able to overcome liquid-liquid intermolecular forces. At this point, cavitation bubbles will form from gas nuclei in the liquid (Soria and Villamiel, 2010). After a few cycles, the gas bubbles will grow in size and then collapse violently. The collapsing bubbles will result in accumulated energy hotspots, with high pressure of 5 000 K and pressure of 1 000 bar (Herceg and Jambrak, 2015). The chemical effect of cavitation is still uncertain, although two theories have been proposed – namely the *hotspot theory* and *electrical theory* (Herceg and Jambrak, 2015).

Gao et al. (2018) have described a novel ultrasound-assisted lye peeling regime for tomatoes that reduced the use of lye and favoured yield and lycopene retention. This novel technique improved the environmental friendliness of the lye-peeling process while still enabling 100% peelability. The use of ultrasonic cleaning for potential water recycling has been investigated by Anese et al. (2015) in the fresh-cut industry. They concluded that the use of ultrasound *in situ* was effective in achieving a 5-log reduction in *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella enterica* after five minutes. The application of the technology was also seen as cost effective and able to meet existing safety criteria.

Microwave processing

Microwave (MW) heating results from the dissipation of electromagnetic waves in the target medium (Perino-Issartier et al*.,* 2011). Unlike conventional practices, the heating is not restricted to thermal conduction or convective currents, which means that more rapid temperature increases can be obtained (Perino-Issartier et al., 2011).

MW processing has already found its way into commercial operations, being the second most widely applied novel/'green' technology – after HPP (Jermann et al., 2015; Leonelli and Mason, 2010). The technique allows for the effects of many processing techniques to fully reproduced, with numerous added advantages (Chemat et al., 2017). Among these advantages are the shorter processing times involved, reduced processing costs and energy requirements, higher final product purity, and negation of wastewater treatment (Chemat et al., 2017; Perino-Issartier et al*.*, 2011). However, Perino-Issartier et al*.* (2011) have made note of the fact that continuous MW pasteurisation may come at the expense of increased price and energy consumption.

Typical water-using operations such as sterilisation, extraction, pasteurisation, and blanching have been shown to be reproducible by means of microwave processing (Benlloch-Tinoco et al*.*, 2014; Chemat et al., 2017; Cheng et al., 2011; Viña et al., 2007).

Cold plasma

Plasma can be described as an ionised gas with a wide array of active species and exists as the so-called fourth state of matter. Furthermore, it is present in either a grounded or excited state, possessing a net-neutral charge (Chizoba Ekezie et al*.,* 2017). Within the food industry, non-thermal plasma generated by electrical discharges is of particular interest due to its processing ability at low temperatures (Chizoba Ekezie et al., 2017).

Cold plasma is an eco-friendly technique (Chizoba Ekezie et al., 2017) with many advantages apart from its water-free application. These include, but are not limited to: high efficiency at low temperatures, 'just-in-time' production of acting agents, a low impact on the internal product matrix, no residual compounds, and improved resource efficiency (Thirumdas et al., 2015). Montenegro et al*.* (2002) have proven the ability of non-thermal plasma treatment to achieve up to a 7-log reduction in apple juice inoculated with *E. coli* 0157:H7. Benghanem (2016) has demonstrated the ability of cold plasma to decontaminate wastewater from date palm and tomato-processing facilities after exposure of 130 and 150 seconds, respectively. The atmospheric pressure plasma jet also showed its ability to improve the COD of the wastewater by between 58% and 93%, while also reducing endotoxin loads by up to 90%.

Pulsed electric field processing

Pulsed electric field (PEF) processing is a non-thermal technique that exposes biological cells to an electric field of sufficient strength to induce electroporation (Toepfl et al*.,* 2006). PEF has been successfully used for tomato peeling (Arnal et al., 2018) and the pasteurisation of fruit juices. It has been shown to improve the efficiency of drying operations and has also demonstrated the ability to disintegrate excess sludge produced during wastewater treatment (Toepfl et al., 2006). Arnal et al. (2018) used a life cycle analysis (LCA) in a case study to determine the environmental advantages of PEF in tomato peeling. They concluded that the incorporation of the technology reduced steam requirements in the thermophysical peeling stage by 20%.

PEF was found to be the third most commercially adopted novel technique according to a global survey by Jermann et al. (2015).

Infrared (IR)

To counter the typically high water and energy requirements of lye and steam peeling in the processed tomato industry, Vidyarthi et al. (2018) have suggested IR peeling as an alternative. Their study revealed that IR dry peeling offered lower peeling losses (up to 12%) and a firmer peeled product (up to 38%) when compared to conventional lye peeling. Improved peelability and colour were also apparent. Likewise, Pan et al. (2015) have also demonstrated the viability of IR dry peeling in tomatoes to counter the typically high water and chemical use associated with the conventional process.

Ohmic heating

Ohmic heating, also known as joule heating, is the process whereby an electrical current is passed through a food medium for the purpose of heat generation (Chen, 2015). The rate of heating is dependent on the voltage gradient as well as the electroconductivity of the food – thus making non-ionic mediums like oil unsuitable (Chen, 2015).

Gupta and Sastry (2018) have demonstrated the desirable synergistic effects of ohmic heating and a 2% lye solution during pear peeling when compared to the traditional 18% solution used in industry. The technique was able to significantly improve peel yields while reducing the negative environmental impacts associated with the conventional process (the presence of large amounts of NaOH in the effluent). Likewise, Wongsa-Ngasri and Sastry (2015) have shown the potential of ohmic heating for tomato peeling. Sensoy and Sastry (2004) have also reported on the effectiveness of OH when used to blanch mushrooms. The technique was able to avoid the high consumption of water associated with conventional blanching while still offering a high-solids content during the process.

High-pressure processing

High-pressure processing (HPP), also known as high-hydrostatic processing (HHP), is considered to be a waste-free, environmentally friendly process (Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Pereira and Vicente, 2010). The technology is especially prevalent in food industries where traditional heat treatments pose a threat to organoleptic and nutritional characteristics (Bermúdez-Aguirre and Barbosa-Cánovas, 2011; Perrut, 2012). HPP was found to be the most widely adopted novel/'green' technology in a global survey by Jermann et al. (2015). The basic process involves loading food products into a high-pressure vessel, which is in turn filled with a pressure-transmitting fluid (usually water). Additional fluid is then pumped into the chamber for pressurisation. The pressure is then maintained for a specified amount of time, after which the vessel is depressurised and the food product removed (Karwe et al., 2015). However, it must be noted that complete spore inactivation is usually not possible without a combination of high pressure *and* high temperature, accomplished by a process known as PATS (pressure-assisted thermal sterilisation; Bermúdez-Aguirre & Barbosa-Cánovas, 2011; Karwe et al., 2015).

Supercritical fluids

A supercritical fluid (SCF) can be defined as having a temperature and pressure higher than those at the critical point (Thereza et al., 2015). Supercritical fluids have been suggested as a 'green' technological alternative to conventional (also water- and energy-intensive) pasteurisation and sterilisation techniques (Chemat et al., 2017; Perrut, 2012). The previously described high pressure processes have a drawback in that extremely high pressures (and associated high costs) are required for effective sterilisation of the food product in question (between 4 000 and 8 000 bar; Perrut, 2012). It is in light of this that supercritical fluid exposure at lower pressures has emerged as an alternative sterilisation technique (Perrut, 2012). For example, complete sterilisation of *Alicyclobacillus acidoterrestris* spores in commercial apple juice was accomplished by Bae et al. (2009) at 100 bar for 40 minutes with temperatures of 65 ºC and 70 °C for 30 minutes at 80 bar.

Ultraviolet pasteurization and sterilisation

Ultraviolet (UV) radiation describes a wide range of wavelengths in the non-ionising region of the spectrum, with wavelengths of between 200 nm (x-rays) and 400 nm (visible light; Ibarz et al., 2015). In the food industry, UV-C (wavelengths between 200 and 280 nm) has been used to decrease the microbial load in the following products and processes (Ibarz et al., 2015):

- Air in meat or vegetable processing
- Water to be used in later processing (thus, it also has a use in internal reuse/recycling)
- Disinfection of the surfaces of fresh products
- Liquid foods such as milk, juice, and cider

As an example, Tremarin et al. (2017) have demonstrated the ability of UV-C to achieve a 5-log reduction of *A. acidoterrestris* in apple juice, which was found to be more effective than a 95 °C thermal treatment for the same amount of time (eight minutes).

CHAPTER 9: KEY FINDINGS AND FURTHER WORK

KEY FINDINGS

A key feature of the present FVPI is its strong export-oriented approach to production and its focus on intra-Africa trade. The pivotal commodities in the industry are fruit-juice concentrates and canned vegetable products with a production value in 2014 of slightly over ZAR 10 billion and ZAR 6 billion, respectively. Another important aspect of the industry is its highly competitive and concentrated nature, with a few key players heading both production and employment. The locations of processing facilities are generally determined by the proximity of the raw inputs, with only a few exceptions. The Western Cape was found to be the leading host of processing facilities, where the juicing and canning of deciduous fruits dominates. The Eastern Cape, the Northern Cape, Limpopo, and Mpumalanga also played host to their fair share of fruit and vegetable processing.

It is encouraging that some of the facilities reported SWI figures comparable or better than that of their international counterparts. In addition to this, some facilities did perform well in relation to the SWIs established for certain products in the original 1987 NATSURV. Many of the facilities have dedicated long-term strategies for improving water use, with one facility in particular having almost halved water consumption over a three-year period. In general, raw materials and facility cleaning were found to be the main consumers of water; therefore, initial water savings endeavours should be directed at these operations.

However, it must be noted that improvements in water efficiency in the South African FVPI are not only motivated by desire for environmental protection or drought risk, but also for financial reasons. The costs of water consumption and effluent disposal can be reduced by improving the water efficiency of the processes.

With regards to wastewater management, it can be concluded that advanced treatments are not generally practiced within the industry. While most facilities perform at least a primary wastewater treatment, there seems to be less motivation for facilities to invest in secondary treatments – possibly due to the lengthy pay-back periods associated with the capital expenditure. Only three facilities of the 19 included in the final sample practiced advanced/tertiary treatment. The choice of disposal routes for the final effluent was also determined by the nature of the surroundings. Rural settings most commonly used irrigation as the preferred disposal route, while in urban environments municipal wastewater systems were the preferred disposal routes.

Water use

The OABS (2019) report concludes that, in general, ratios for water use per product processed reported during interviews indicate that most of the industries made remarkable progress in reducing their water use per unit of output (efficiency gains) during the drought compared to before the drought (albeit with significant investments in water-demand management technologies and practices). The canned fruit and table olive industries in particular managed to reduce their water use by 20–25%. According to the report, some industries are already doing their best – such as the wine and juice industry that are close to the international benchmarking standards (OABS, 2019).

Water-scarcity resilience

Water quality was reported as vital both in the processing stage and as an ingredient in some products (e.g. beverages). The pre-filtration of municipal water with carbon filtration systems was required for some industries to ensure that they comply with food and health safety standards to remain internationally competitive (protecting their reputation) and to ensure resilience to lower water quality impacts (OABS, 2019).

Water tariffs were increased for industries during the restrictions, but not with the same harsh tariffs as for household water use, although the total water-use requirements were high in some cases. Production costs generally increased. The cost could not be passed on to the consumer, which resulted in reduced profit margins and therefore reduced financial resilience to water restrictions (OABS, 2019).

Loadshedding of electricity had a significant impact on the agri-processing sector, as it disrupts the processing of products and in many cases results in damaged/spoilt products that need to be dumped due to either poor quality or hygiene risks. In most facilities, the equipment needs to be cleaned after a loadshedding stoppage, resulting in additional washing water being used and causing downtime during production. This downtime can necessitate that additional hours/overtime have to be worked to process products within specified time limits.

Identified barriers to water resilience

Although the emphasis of OABS report (2019) was on the improvement of agri-processing economic water resilience, it is important to understand that water resilience is only one element of agricultural value chain resilience. The following barriers to increasing water resilience were identified:

- Lack of proper maintenance and refurbishment of infrastructure: Income derived from water sales/tariffs is not ringfenced for this purpose. Lack of technical expertise and knowledge in some local authorities result in the poor maintenance and management of their water infrastructure. This can result in excessive water losses and water use which is unaccounted for.
- The quality of the water provided to users can sometimes be below acceptable standards during low levels at storage facilities or due to leaks in distribution systems. This can seriously impact on the agri-processing sector, which relies on water of a very good quality to meet hygiene requirements.
- The impact of very high water tariffs during water restriction periods on the financial viability of the agri-processing sector is significant. It was requested by interviewees that this be brought to the attention of local authorities. These companies buy large volumes of water from their water-service providers (municipalities), contribute towards the income of the local authority through their rates

and taxes, and provide job opportunities to many people in that town. The financial viability of the agri-processing companies is severely negatively affected by the high water tariffs, which can be detrimental for local authorities if more industries acquire their own water sources and go off-grid.

- Loadshedding of electricity is a key constraint and impacts on the competitiveness of agri-businesses since it has significant water-use efficiency and cost implications for some agri-processors.

Interventions proposed by stakeholders (as per excerpt from OABS, 2019)

A number of interventions were proposed in the OABS report by stakeholders in the FVPI, which are provided verbatim as follows:

- Public perceptions of the reuse of wastewater within the food industry should be changed through education and capacity-building programs to create an understanding of the safety of reuse systems.
- Water augmentation options should also include desalination of seawater, the development of groundwater resources, and the reuse of treated effluent to create increased resilience through diversification. Current water supply options are all reliant on surface water (rainfall), which results in an unacceptably high water undersupply risk for the agri-processing sector.
- Improved maintenance of bulk water infrastructure by local authorities is required to reduce losses in water supply systems. This will also ensure that all possible winter surface-water runoff is captured in storage dams and then made available to water users.
- Water-saving incentives and financial support from local authorities/government are required to support agri-businesses in embarking on water-saving initiatives. The very low profit margins of the dairy processors limit their ability to embark on these initiatives without support. The reduced water demand resulting from these initiatives can be regarded as water augmentation options for local authorities.
- Agri-processing companies can sponsor water-efficient appliances/technologies for their staff to implement at their houses. Some companies support their staff by providing information, but not appliances/technologies.
- The metering of water throughout the agri-processing phases should be standard practice, as it can indicate critical areas where water savings can be achieved. This can include real-time monitoring. Water metering information can be included in the technology hub.
- Water audits can assist in increasing water-use efficiency. The National Cleaner Production Centre South Africa (NCPC-SA) continues with its drive to raise awareness in industry and government about the importance of water management. Through its Industrial Water Efficiency (IWE) Project, companies can apply for free water assessments and assistance with implementing water efficiency in their plants (Engineering News, 2018).

NEW RESEARCH

A number of aspects affecting the FVPI in South Africa need to be addressed to ensure the competitiveness of the local industry in global markets. Some of these include impact of the COVID-19 pandemic, local and global pricing pressures, water scarcity during periods of drought, the impact of poor economic performance periods on the industry, export regulations, and changing consumer trends.

Regarding water and wastewater management in these industries in particular, the challenges for the producers include water availability (especially during periods of water scarcity) and water quality. Because of the high water-quality requirements for process water in the food industry, water recycling presents a number of challenges when considered as and option to reduce the freshwater intake of the industries; there is a big need for further research on this and related topics.

Other opportunities for further research and project development include the improvement of licensing processes (reduce the ever-increasing delays in obtaining the necessary permissions), improved cooperative governance, groundwater (versus surface water) use, the improvement of sensing and flow measurement technologies, and establishing effective partnerships.

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APPENDIX A: STAKEHOLDER ENGAGEMENT WORKSHOPS AND KNOWLEDGE DISSEMINATION

Two workshops were held with stakeholders and roleplayers in the sector to present the work that had been done by the time the first workshop was held in October 2020 and to solicit inputs for the final report. The first, the NATSURV 14 Project Workshop, was a webinar that took place on 29 October 2020, while the second workshop formed part of the WISA 2020 Biennial Conference and was held on 10 December 2020 (also online). At the workshops, the draft NATSURV 14 document was presented to the sector, discussions held, and inputs on improvement of the document solicited.

WORKSHOP 1

WRC STAKEHOLDER ENGAGEMENT WORKSHOP

29 OCTOBER 2020

This workshop was presented as the formal knowledge dissemination deliverable of the project, which aimed to not only engage with all the stakeholders and roleplayers in the fruit and vegetable processing sector, but also on a wider basis with roleplayers in the water sector (researchers, academia, consulting engineers, and the local, provincial, and national authorities). The workshop was presented as a virtual event in the form of a webinar and was hosted by the WRC.

Presentations were made by the project Leader and two master's students from Stellenbosch University, as well as by the Departmental Chair: Food Science at Stellenbosch University, the South African Fruit Juice Association/South African Fruit & Vegetable Canning Association, and the National Centre for Cleaner Production (NCPC, CSIR).

The invitation to the workshop and the workshop program is shown below, followed by the presentations of SAFJA/SAFVCA and NCPC.

Water Research Commission Workshop

WATER AND WASTEWATER MANAGEMENT IN THE SOUTH AFRICAN FRUIT AND VEGETABLE PROCESSING INDUSTRY

Virtual workshop on MS Teams

Thursday 29 October 2020 from 10:00 - 13:00

During the middle 1980s the Water Research Commission (WRC), with the support of the Department of Water Affairs and Forestry (now the Department of Human Settlements, Water and Sanitation) commissioned a series of surveys relating to water use and wastewater treatment practices in industry. The purpose of these NATSURVs (as they later became known) was to determine minimum specific water intake requirements so that during times of drought, blanket restrictions would not impose an unfair burden on certain facilities. The surveys were also used by regulators to manage wastewater discharges in order to protect downstream infrastructure and treatment facilities, and the environment in general. The original NATSURVs have been used by academia, industry, regulators, and consulting engineers as a valuable benchmarking platform for the last three decades.

One has only to look at the recent drought as evidence for the water-stressed (and arguably water scarce) nature of our country. Considering this, it can be argued that an increased focus on water use and wastewater management practices is required to ensure the environmental feasibility of the private sector, which forms the backbone of the economy.

Since 2013, the WRC has been actively updating the NATSURVs. This was done in response to fact that South Africa's industrial landscape has changed significantly in the last three decades. In addition to this, novel technologies and process advances may have had noticeable impacts on water consumption and/or wastewater treatment efficiencies.

Updating of the NATSURV for the fruit and vegetable processing industry commenced in 2018 with the aim of developing a comprehensive, representative and relevant industry benchmark update that has the support of all stakeholders and role-players of this agri-processing sector. During the past two years the project team from Stellenbosch University (SU) has been engaged in information gathering initiatives through questionnaires, interviews, and industry visits. The end-product of the project will be a new NATSURV document for the fruit and vegetable processing industry, containing all the latest information and figures for this sector.

The aim of the workshop is to present the draft NATSURV document to the stakeholders and role-players in the fruit and vegetable processing industry, on a national basis.

We therefore wish to invite you to participate in this workshop during which the results and draft guidelines document of the project will be presented to the industries, municipalities, provincial and national government, research institutes, consulting engineers and other role-players with interest in this field.

10:00	Welcome to the Workshop	Dr John Zvimba, *WRC Research Manager*
10:10	Aims of the Workshop, Programme	Chris Swartz, *Project Leader*
10:20	Introduction to the Food Processing Industry	Prof Gunnar Sigge, HOD *Food Science, SU*
10:30	Overview of the Fruit and Vegetable Processing Industry in South Africa (SAFVCA/SAFJA)	Rudi Richards, *SAFJA* Jill Atwood-Palm, *SAFVCA*
10:50	An introduction to the NATSURV 14 project	Chris Swartz
11:10	Investigating Water and Wastewater Management in the South African Fruit and Vegetable Processing Industry	Pierre Volschenk, *Postgraduate Student, SU*
11:40	**BREAK**	
11:50	Resource Efficient Cleaner Production (RECP) in the Food Processing Industry	Brent Goliath, NCPC, CSIR
12:10	Wastewater treatment in the Fruit and Vegetable Processing Industry	Christiaan van Schalkwyk, *Postgraduate Student, SU*
12:30	Discussion	All
12:50	Closure. The Way Forward	Chris Swartz

WORKSHOP PROGRAMME


NATIONAL CLEANER PRODUCTION CENTRE
SOUTH AFRICA
NCPC
Agro-processing Sector
Assessment Report Review Process
29 October 2020
Brent Goliath – Project Manager – CPT, NCPC-SA
www.ncpc.co.za
the dtic
CSIR


NCPC
The National Cleaner Production Centre South Africa (NCPC-SA) supports South African industry to improve competitiveness and reduce environmental footprint through the implementation of resource efficient and cleaner production (RECP) methodologies.
A programme of the dtic hosted by the CSIR
the dtic
Department:
Trade, Industry and Competition
REPUBLIC OF SOUTH AFRICA
CSIR
www.ncpc.co.za


Thematic approach – flagship projects
• The NCPC-SA applies RECP in three main thematic areas. Each of these is driven through a flagship project or programme:
NCPC-SA
+ partners
Water
Industrial Water Efficiency Project
Materials & waste
Industrial Symbiosis Programme
Energy
Industrial Energy Efficiency Project
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Services to industry
The NCPC-SA services are highly subsidised, and are aimed at stimulating and supporting the uptake of RECP by industry:
Assessments & Implementation
Energy, water, materials, waste efficiency
Skills development
Training courses
Internship programme
RECP Tools
Online tools and sector guides
Advocacy
Workshops, awareness & policy advice
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SOUTH AFRICA
Agro-processing Sector
Report Review Process
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Disclaimer

- The results shared from the NCPC-SA Agro-processing Sector Report Review is currently a "work in progress" and will undergo a review before being finalised.

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Agro-processing – Water - Assessment Reports

RECP Reports	No of Companies	% Representation
Effluent & Water	1	1%
FSO	1	1%
IEE	2	2%
IWE	16	17%
RECP	71	75%
SSO	4	4%
Grand Total	95	100%

The results shared from the NCPC-SA Agro-processing Sector Report Review is currently a "work in progress" and will undergo a review before being finalised.

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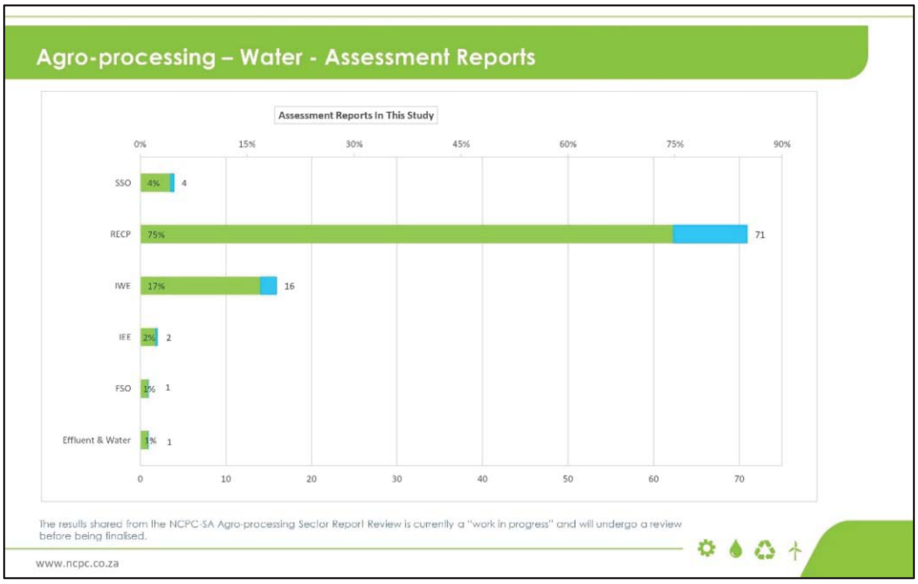

Agro-processing – Water Reports - Provincial Footprint

SA Provinces	Reports Per Province
EC	1
GP	28
KZN	16
LIMPOPO	2
NC	2
NW	3
POLOKWANE	1
WC	42
Grand Total	95

The results shared from the NCPC-SA Agro-processing Sector Report Review is currently a "work in progress" and will undergo a review before being finalised.

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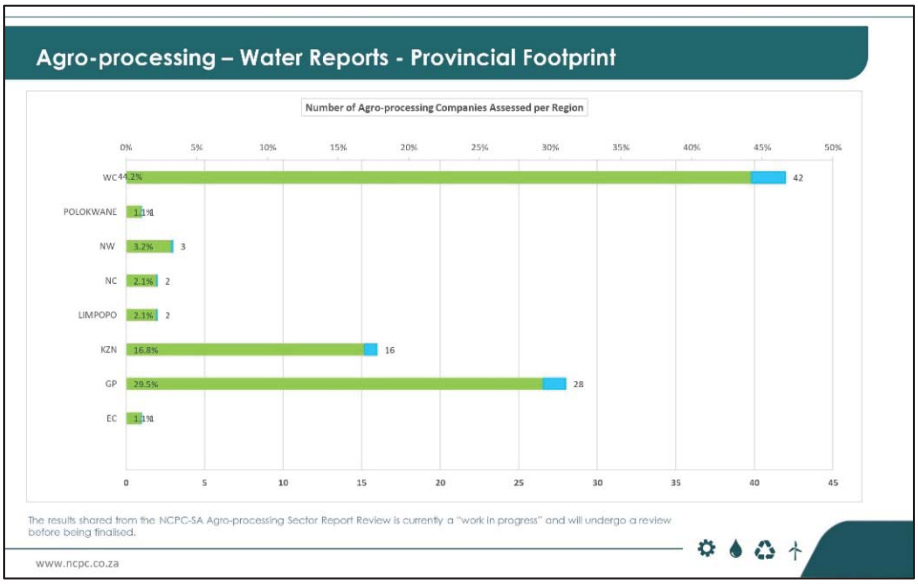
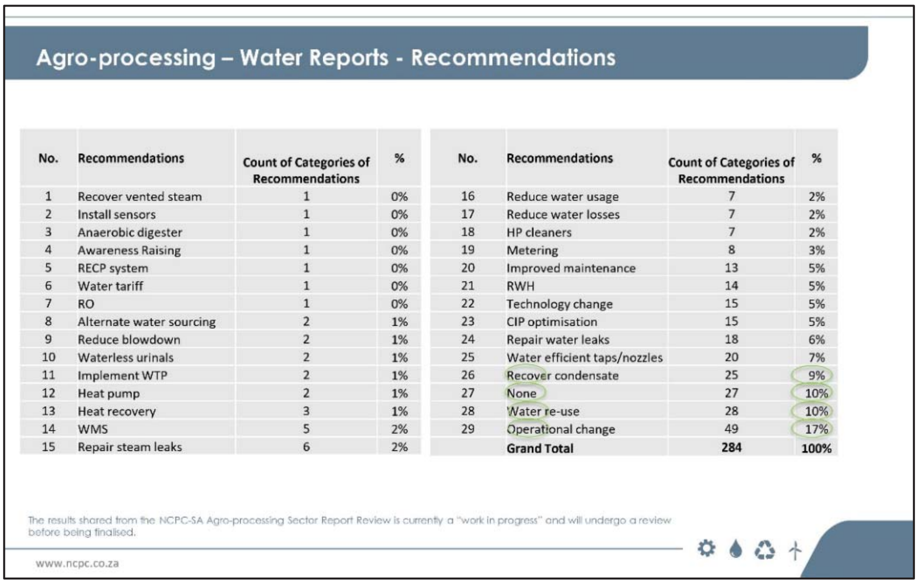
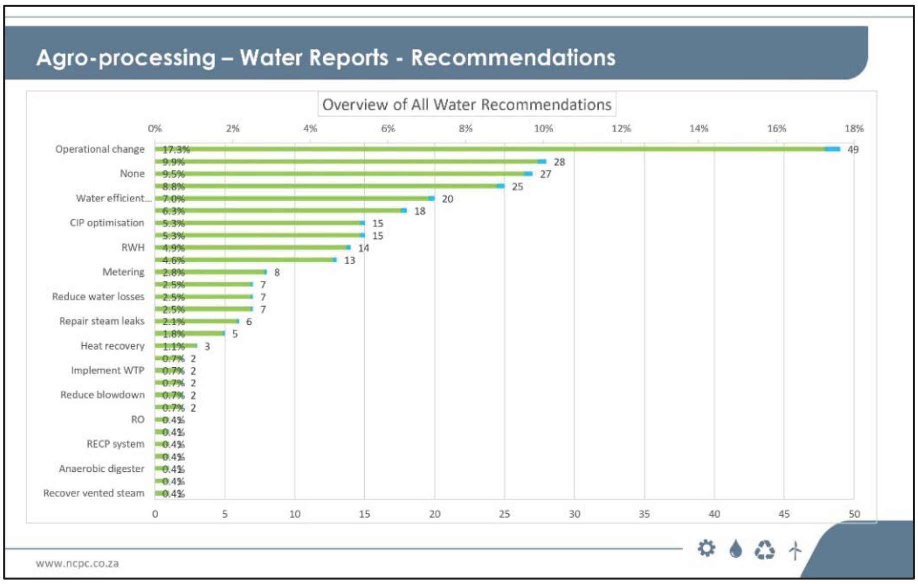
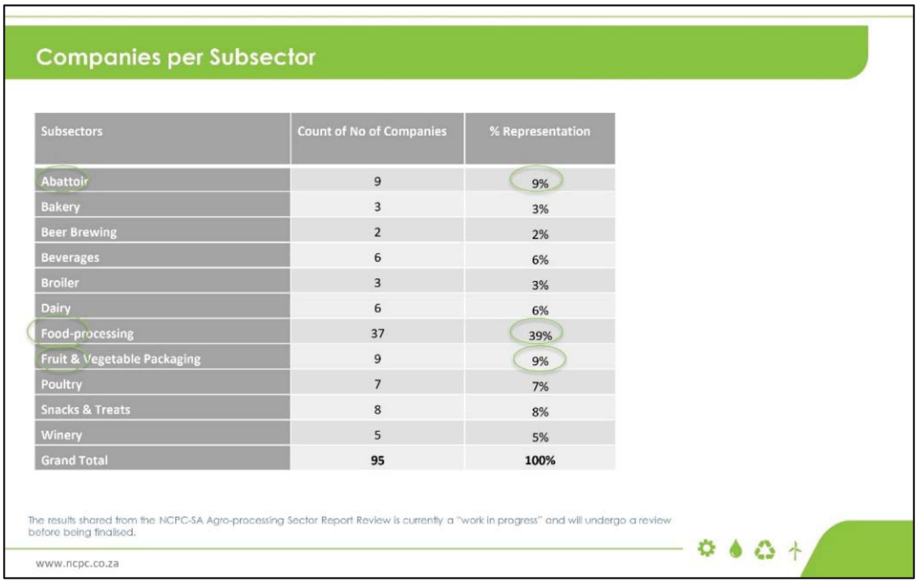




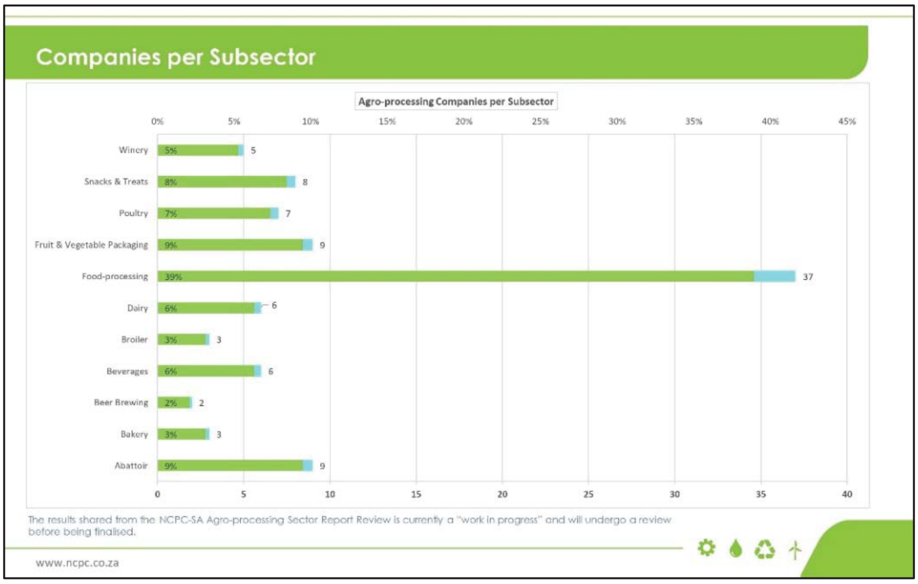
Agro-processing – Water Reports - Recommendations

No.	Recommendations	Count of Categories of Recommendations	%	No.	Recommendations	Count of Categories of Recommendations	%
1	Recover vented steam	1	0%	16	Reduce water usage	7	2%
2	Install sensors	1	0%	17	Reduce water losses	7	2%
3	Anaerobic digester	1	0%	18	HP cleaners	7	2%
4	Awareness Raising	1	0%	19	Metering	8	3%
5	RECP system	1	0%	20	Improved maintenance	13	5%
6	Water tariff	1	0%	21	RWH	14	5%
7	RO	1	0%	22	Technology change	15	5%
8	Alternate water sourcing	2	1%	23	CIP optimisation	15	5%
9	Reduce blowdown	2	1%	24	Repair water leaks	18	6%
10	Waterless urinals	2	1%	25	Water efficient taps/nozzles	20	7%
11	Implement WTP	2	1%	26	Recover condensate	25	9%
12	Heat pump	2	1%	27	None	27	10%
13	Heat recovery	3	1%	28	Water re-use	28	10%
14	WMS	5	2%	29	Operational change	49	17%
15	Repair steam leaks	6	2%		Grand Total	284	100%





Subsectors	Count of No of Companies	% Representation
Abattoir	9	9%
Bakery	3	3%
Beer Brewing	2	2%
Beverages	6	6%
Broiler	3	3%
Dairy	6	6%
Food-processing	37	39%
Fruit & Vegetable Packaging	9	9%
Poultry	7	7%
Snacks & Treats	8	8%
Winery	5	5%
Grand Total	95	100%



No. of Companies vs No. of Recommendations

Subsector	No. of Companies	No. of Recommendation Types	Difference
Abattoir	9%	8%	-1%
Bakery	3%	2%	-1%
Beer Brewing	2%	5%	2%
Beverages	6%	11%	4%
Broiler	3%	2%	-1%
Dairy	6%	10%	4%
Food-processing	39%	35%	-4%
Fruit & Vegetable Packaging	9%	6%	-4%
Poultry	7%	8%	1%
Snacks & Treats	8%	10%	1%
Winery	5%	3%	-2%
Grand Total	**100%**	**100%**	

The results shared from the NCPC-SA Agro-processing Sector Report Review is currently a "work in progress" and will undergo a review before being finalised.

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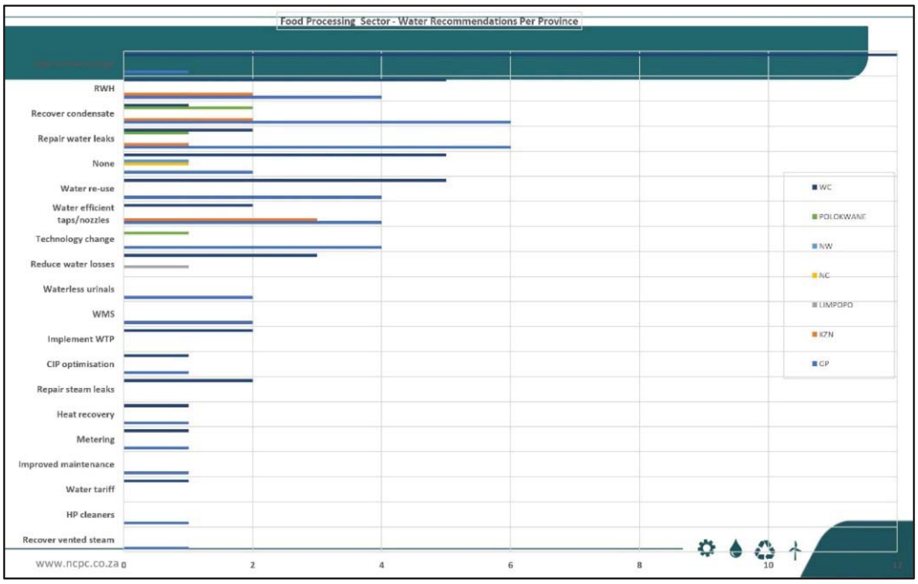
RECOMMENDATIONS	GP	KZN	LIMPOPO	NC	NW	POLOKWANE	WC	GRAND TOTAL
Recover vented steam	1							1
HP cleaners	1							1
Water tariff							1	1
Improved maintenance	1							1
Metering	1						1	2
Heat recovery	1						1	2
Repair steam leaks							2	2
CIP optimisation	1						1	2
Implement WTP							2	2
WMS	2							2
Waterless urinals	2							2
Reduce water losses			1				3	4
Technology change	4					1		5
Water efficient taps/nozzles	4	3					2	9
Water re-use	4						5	9
None	2			1	1		5	9
Repair water leaks	6	1				1	2	10
Recover condensate	6	2				2	1	11
RWH	4	2					5	11
Operational change	1						12	13



Agro-processing – Water – Recommendations - Feasibility Analysis

Subsectors	Investment Cost (Rand)	Savings (kL)	Savings (Rands)	Ave Payback (yrs)
Abattoir	R2,005,000	79,499	R3,706,336	17.5
Bakery	R403,500	36	R378,730	1.7
Beer Brewing	R2,455,000	233,049	R1,778,000	1.4
Beverages	R8,388,192	103,064	R6,696,247	2.8
Broiler	R71,240	178	R103,383	3.6
Dairy	R7,432,170	285,430	R12,449,240	3.0
Food-processing	R21,290,865	1,254,590	R14,208,805	12.0
Fruit & Veg Packaging	R1,764,265	118,676	R1,589,110	2.1
Poultry	R24,060,600	830,053	R15,227,887	2.5
Snacks & Treats	R16,702,912	300,826	R11,887,666	3.0
Winery	R211,650	16,876	R150,756	1.1
Grand Total	R84,785,394	3,222,277	R68,176,160	-

The results shared from the NCPC-SA Agro-processing Sector Report Review is currently a "work in progress" and will undergo a review before being finalised.

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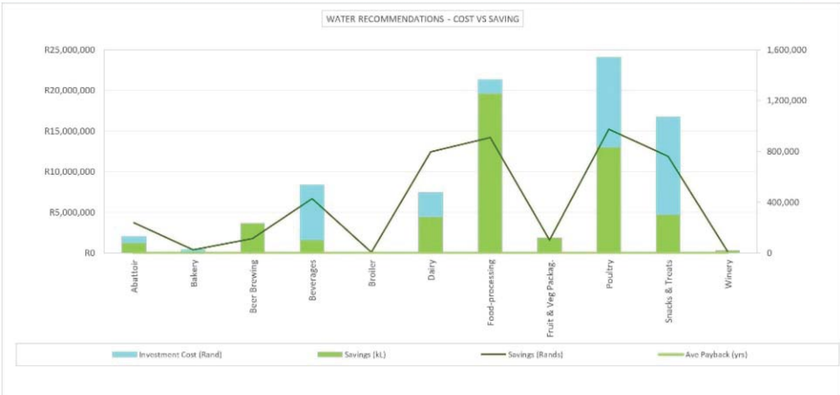
Agro-processing – Water – Recommendations - Feasibility Analysis



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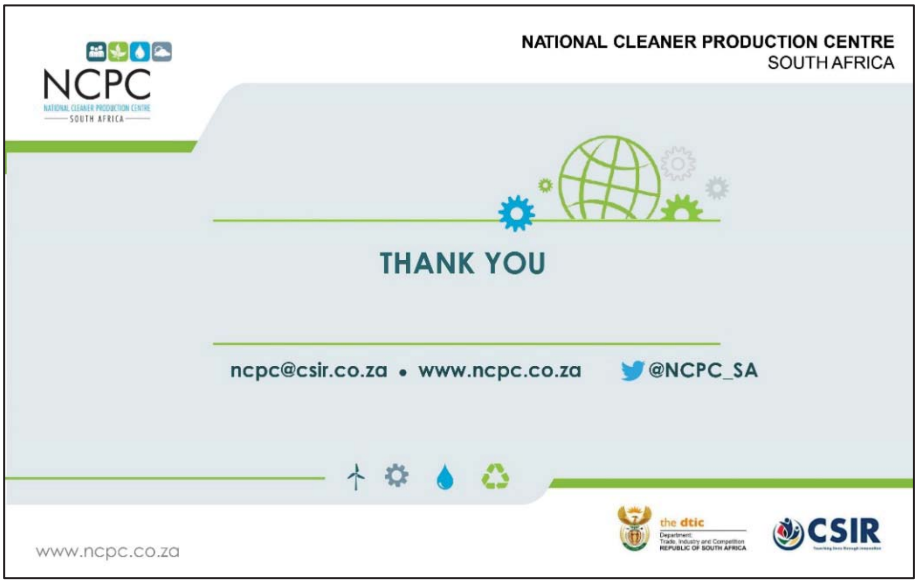
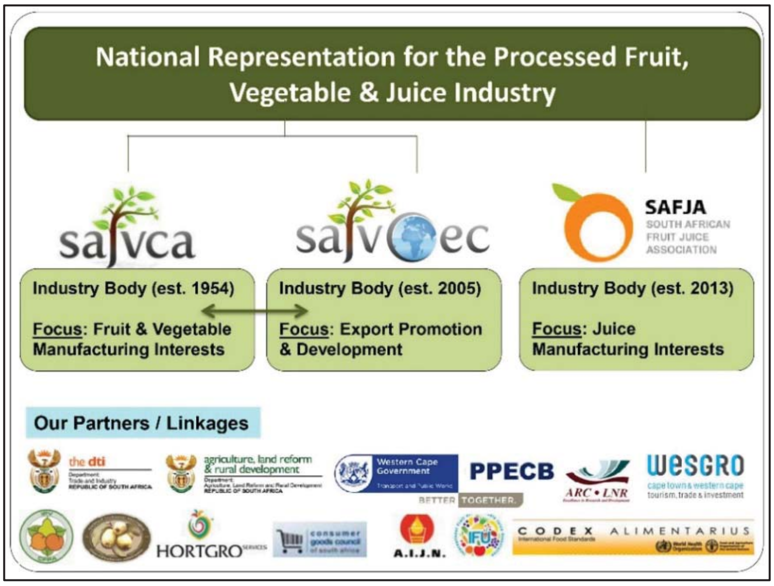
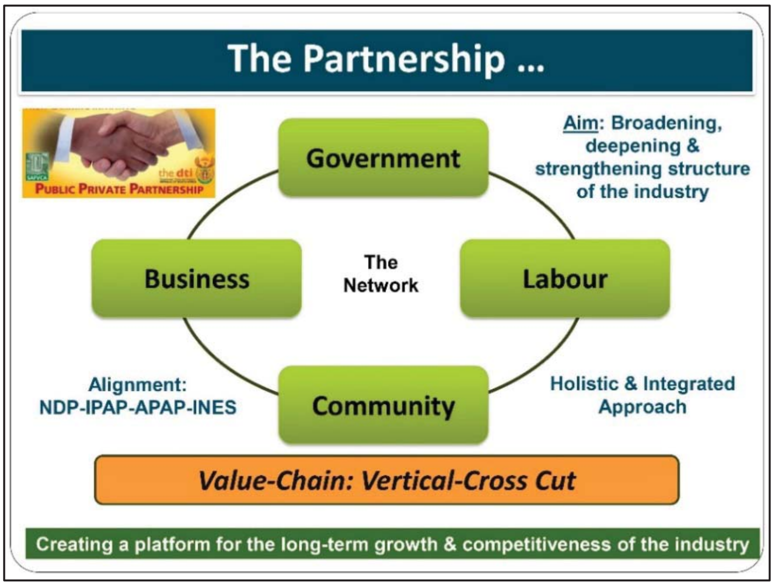
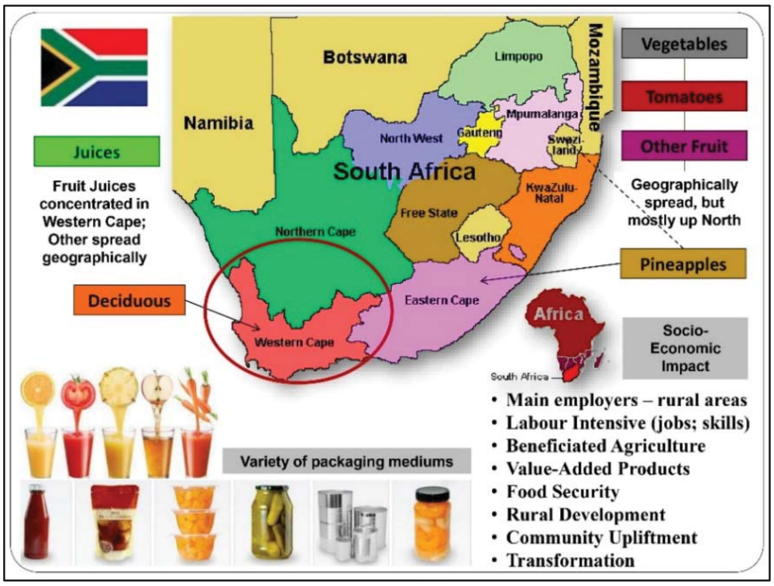

NATIONAL CLEANER PRODUCTION CENTRE
SOUTH AFRICA
NCPC
THANK YOU
ncpc@csir.co.za • www.ncpc.co.za
@NCPC_SA
www.ncpc.co.za
the dtic
CSIR

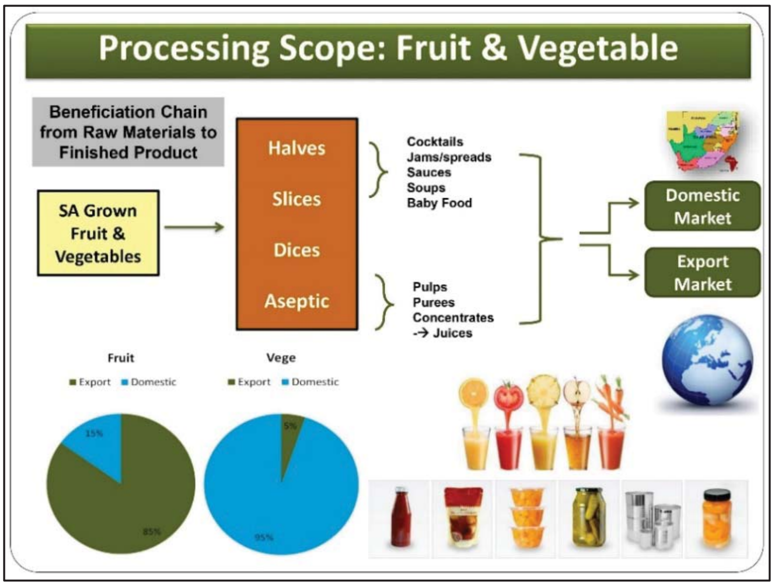

Webinar
Presentation:
Water & Wastewater
Management in the
Processed Fruit &
Vegetable Industry
29 October 2020
Presented By:
Jill Atwood-Palm &
Rudi Richards
Overview of the South African
Processed Fruit, Vegetable & Juice
Industry (SAFVCA & SAFJA)


General Profile of the Industry
Value-Chain: Beneficiation & Value Addition
Primary Agriculture
Agro-Processing
Consumer


National Representation for the Processed Fruit, Vegetable & Juice Industry
safvca
safvec
SAFJA
SOUTH AFRICAN FRUIT JUICE ASSOCIATION
Industry Body (est. 1954)
Focus: Fruit & Vegetable Manufacturing Interests
Industry Body (est. 2005)
Focus: Export Promotion & Development
Industry Body (est. 2013)
Focus: Juice Manufacturing Interests
Our Partners / Linkages
the dti
agriculture, land reform & rural development
Western Cape Government
BETTER TOGETHER.
PPECB
ARC • LNR
wesgro
cape town & western cape tourism, trade & investment
HORTGRO
consumer goods council of south africa
A.I.J.N.
IFU
CODEX ALIMENTARIUS


The Partnership ...
the dti
PUBLIC PRIVATE PARTNERSHIP
Government
Aim: Broadening, deepening & strengthening structure of the industry
Business
The Network
Labour
Alignment: NDP-IPAP-APAP-INES
Community
Holistic & Integrated Approach
Value-Chain: Vertical-Cross Cut
Creating a platform for the long-term growth & competitiveness of the industry


Botswana
Limpopo
Mozambique
Vegetables
Tomatoes
Other Fruit
Namibia
Mpumalanga
North West
Gauteng
Swaziland
South Africa
Juices
Fruit Juices concentrated in Western Cape; Other spread geographically
KwaZulu-Natal
Free State
Geographically spread, but mostly up North
Northern Cape
Lesotho
Pineapples
Deciduous
Eastern Cape
Africa
Western Cape
Socio-Economic Impact
South Africa
• Main employers – rural areas
• Labour Intensive (jobs; skills)
• Beneficiated Agriculture
• Value-Added Products
• Food Security
• Rural Development
• Community Upliftment
• Transformation
Variety of packaging mediums



Industry Attributes ...

- **Well-established** and **organized** Industry
- **Reliable Supply** & **Quality** of raw & finished products
- Strong **Manufacturing Capability** with **World Class** Standards
- **Experienced Manufacturers** with proven track record & reputation
- **Premium Quality** Value-added Products
- **Strong** and **Reputable** Brands
- **Robust, safe** and **stable** packaging across all mediums
- Highly **Nutritional** Products (antioxidants, vitamins, protein, etc)
- Proudly **South African** products (high local content)

General Profile of the Industry

- **Agro-Processing Sector:**
  - Processed Fruit & Vegetables; Manufacturers of Value-Added Products
  - Products are more than 90% of local origin *(Imports i.e. Pines; Cherries, Tinplate)*
  - Supports over 200,000 dependants in rural areas across South Africa
- **Farming:**
  - Fruit: Over 500,000 tons; Vegetables: 250,000 tons processed annually
  - Sourced from approx. 2,000 farms; employing close to 30,000 farm workers
- **Manufacturing:**
  - SA/SACU: 3 large scale fruit canning factories, 3 jam units, over 20 fruit concentrate/juice factories; over 10 vegetable/related units (spread nationally)
  - Labour-intensive environment; close to 20,000 factory workers

safvca

Size of the Industry: Value

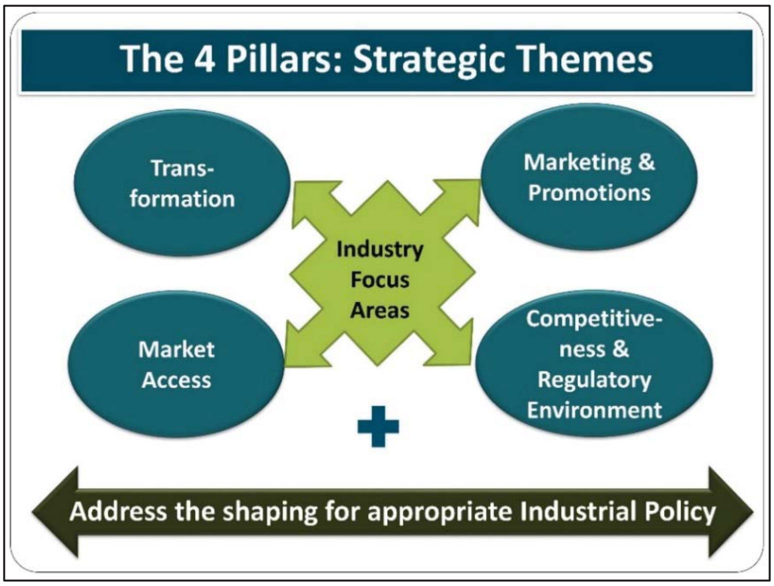
- **Scope of the Industry:** **Chapter 20** of Tariff Book (Fruit, Vege & Juices)
- **Domestic Market:** ZAR 12,000,000 (*Nielsen Category Data*) – incl. Juices
- **Export Markets:** ZAR 8,820,333 (*2018 Trademap*)

HS 2001 – HS 2006 VEGE	HS 2007–HS 2008: FRUIT	HS 2009: JUICE/CONC
ZAR 1,500,304 (17%)	**ZAR 3,191,586 (36%)**	**ZAR 4,128,443 (47%)**
Botswana	United Kingdom	Netherlands/EU
Namibia	SACU (BLNE)	Botswana
Germany	China (Greater)	Namibia
Zambia	Australia	Mozambique
Eswatini	Russia	United States
Zimbabwe	Netherlands/EU	Japan
United States	Japan	Zambia

Chapter 20 Continental Split	AFRICA 42%	ASIA 15%	AMERICAS 7%	EUROPE 31%	OCEANIA 5%
	T-FTA; C-FTA	-	AGOA	EPA; EFTA; Brexit	-

Challenges Facing the Industry

Global Impact	COVID-19 Impact; Protectionist environment; Economic & Pricing Pressures (local/global)
Input Costs / Infrastructure Pressures	High Cost of Production; Energy Supply; Water Quality & Supply; World Pricing pressures (tinplate, sugar, etc); Regulatory pricing (energy, electricity, fuel, etc); Infrastructure: Unreliable & expensive rail/road transportation; High Port Charges and Low Performance
Cost of Capital	High Cost of Capital; Access to Capital
Local Market	Uncontrolled & Non-Conforming Imports Strength of Retailers; Little to no room for negotiation
Farming Sector	Farmer Confidence: Drought; Tree-Pulling; Future Plantings; Climate Change; Farm Costs: Labour; Water & Land Availability
Innovation	Need for New Processing Methods; New Markets; New Packaging Mediums; New Products
Consumer	Changing consumer trends; Drive for Healthy, Safe Food (e.g. Sugar, Sodium Content)
Market Access & Regulatory Environment	Global: Subsidies; High Tariffs; NTB's iro Standards/Regulations; Free Trade Agreements (uneven playing fields); Local Market: Import Duties; Cumbersome Regulatory Environment & Cost of Compliance


The 4 Pillars: Strategic Themes
Trans-
formation
Marketing &
Promotions
Industry
Focus
Areas
Market
Access
Competitive-
ness &
Regulatory
Environment
Address the shaping for appropriate Industrial Policy


Benefits of Collaboration & Partnership
Industry Strategy: Fully integrated across entire value chain
Alignment: NDP 2030; IPAP; INES
Implementation Vehicle for common projects
Representative Platform to address challenges
Elevated Industry Profile with Government
Unified voice to motivate interests and influence policy
Effective, efficient and practical operating model
Cross-Cut of Industry & Key Stakeholders across the value chain
Industry representation at key trade forums, events & initiatives
safvca
safvec
SAFJA

Challenges & Opportunities:
Water & Waste Water Strategy

- ❑ Water Availability & Quality Issues
- ❑ Constraints: Drought; Climate Change; Variable Rainfall
- ❑ Regulatory Framework: Water Regulations
- ❑ Improvement of licencing processes (delays)
- ❑ Coordination & cooperation between levels of Government (and sectors)
- ❑ Waste Water / Effluent Treatment: Partnerships
- ❑ Sustainable use of ground vs surface water
- ❑ "Competition" between agriculture vs urban allocation
- ❑ Smart/digital technology to monitor usage; online licencing, etc
- ❑ Improved water infrastructure (investment, partnerships, tax incentives, etc)


- THANK YOU -

WORKSHOP 2

WISA 2020 VIRTUAL BIENNIAL CONFERENCE

WORKSHOP ON CURRENT NATSURV PROJECTS

10 DECEMBER 2020

This second workshop was presented as part of the Water Institute of Southern Africa's (WISA) Biennial Conference, which is the largest conference on the local water calendar and is attended by the majority of stakeholders, roleplayers, and practitioners in the water sector.

The workshop programme, together with some conference and workshop background information, is presented on the next pages.

BACKGROUND

The management and regulation of industrial water use and effluent production present many challenges, but also significant opportunities for cleaner production and recoverable resources in South Africa.

The NATSURV series of publications were developed by the Water Research Commission of South Africa from the mid-1980's onwards. By conducting national industrial water and wastewater surveys of all classes of industry, water and effluent management and best practice within different important industrial sectors in the South African economy was documented. Due to sector demand, reviews to the series began in 2013. This workshop will focus on recently completed and current NATSURV studies. The aim of the research was to evaluate the industrial processes the specific industries in terms of current practice, best practice and cleaner production, as pertaining to water and effluent management. The regulatory environment within which these industries operate also received specific attention. NATSURV 14: Water and wastewater management in the fruit and vegetable processing industry and NATSURV 16: Water and wastewater management in the Power Generating Industry are revisions of previous editions, whereas NATSURV 18: Water and wastewater management in the pelagic fishing and fish processing industry is the first edition, with this industry not being included in the past.

The workshop will include a presentation of each industry by a specialist and will share research results in terms of a detailed overview of each industry, i.e. its history, growth, economic profile, challenges and opportunities in water and effluent management, as well as each industry's specific water intake, effluent production, recycle and reuse trends, and appropriate technology application. The industries' adoption of concepts such as cleaner production, water pinch, energy pinch, life cycle assessments, and water footprints will also form part of the workshop.

OBJECTIVE

The intended outcome is to inform the target audience of new concepts of water and wastewater management in the relevant industries that can be used to benchmark their practices, and allowing regulators and industries to engage in informed discussions. Consultants working in the various industrial fields will also be informed of the current status quo and potential opportunities.

CONFERENCE SUBTHEMES

The workshop involves aspects of two of the subthemes, namely:

1. Reduce water demand and increase supply; and
2. Govern and regulate the sector.

The aim of the NATSURV series is to define the current status quo in the specific industry in terms of water and wastewater management, but also to provide an opportunity for benchmarking and highlighting industry best practice. This highlights opportunities for industry role players to improve efficiency thereby reducing demand and increasing supply, and provides benchmarking information for regulators in the sector.

SDGs

The following SDGs link to this workshop:

- SDG 6: Clean water and sanitation
- SDG 9: Industry, infrastructure and innovation
- SDG 11: Sustainable cities and communities
- SDG 12: Responsible consumption and production
- SDG 13: Climate action

PROGRAMME

Thursday 10 December 2020: 9h15 – 11h15

Activity	Presenter	Time (min)
Welcome and introduction to the Natsurv Series	Dr John Zvimba (Water Research Commission)	10
Natsurv 19: Water and wastewater management in the fruit and vegetable processing industry (Edition 2)	Mr Chris Swartz (Chris Swartz Engineering)	20
Natsurv 16: Water and wastewater management in the Power Generating Industry (Edition 2)	Dr Gina Pocock (Waterlab)	20
Natsurv 18: Water and wastewater management in the pelagic fishing and fish processing industry (Edition 1)	Mr Bertie Steytler (Watergroup)	20
Open Discussion	Facilitated by Dr Marlene van der Merwe-Botha	20
Conclusion and Close of Workshop	Dr Gina Pocock	10

APPENDIX B: WATER USE SURVEY QUESTIONS (COMPATIBLE WITH ELECTRONIC SURVEY SOFTWARE)

1) Production

(1) What are your main raw product inputs, and how many tons of each fruit or vegetable are produced annually?

(2) Please indicate your production season (months of the year).

2) Water Use

(1) Please provide your total annual water consumption and indicate the primary source of the water (municipal, borehole, river, dam).

(2) Please provide specific water volumes per kilogram or per ton for each fruit or vegetable type produced/processed.

(3) Where is water used in your production process? Please describe and give the approximate percentage consumption for each of the production processes in relation to total use.

3) Water Minimization

(1) On a scale of 1–5 (with 1 = not important and 5 = extremely important), please indicate how important water conservation is in your agenda.

(2) Are water use targets in place?

(3) Are the water use targets being met?

(4) Please indicate the water minimization techniques currently employed at your facility (please tick where appropriate):

- Water pinch and/or other design optimization platforms
- Water reuse and recycling (if selected, indicate how much of the process water is recycled)
- Adoption of water-free operations (if selected, please describe)
- Process control and monitoring
- Avoidance of once-through water use (through recirculation)
- Improved energy efficiency in steam processes

- Water awareness training for staff
- Dedicated maintenance (e.g. leak repair)
- Other (please describe)
- Water-wise cleaning (e.g. HP hoses, CIP etc).

(5) Do you use, or are you planning to use, any of the following novel ‘green’/water-wise technologies to reduce water consumption?

- Instant controlled pressure drop technology (DIC)
- Ultrasound-assisted processing
- Microwave processing
- Cold plasma
- Pulsed Electric Field processing
- Infrared (IR) processing
- Ohmic heating
- High-Pressure Processing (HPP)
- Super critical fluids
- Ultraviolet (UV) processing and/or sterilization
- Other (please describe)

(6) Has the recent drought been a contributing factor in the implementation of water savings measures at your facility? Please rank on a scale of 1–5 (with 1 = not a contributor to 5 = a major contributor)

4) Wastewater generation and management

(1) What is your total estimated annual and daily effluent volume? Please provide estimated percentages of the origin of effluent streams that make up the total effluent volume.

(2) What treatment does the effluent undergo before discharge?

- Primary (please describe)
- Secondary (please describe)
- Tertiary (please describe)

(3) Are wastewater discharge volumes and effluent quality requirements specified in the factory's discharge permit being met? If not, which water quality parameters are exceeding the discharge limits?

(4) Are any of the wastewater or effluent streams reused? Please describe.

5) Energy Use

(1) What are your energy sources? Please select

- Boiler
- Grid (municipal electricity supply)
- Solar
- Biogas from wastewater

(2) What is your total energy use (kWh) in your production processes per day and per annum? Please indicate per product if available.

(3) What is the unit cost (ZAR/kWh) of energy used?

(4) Which gaseous emissions are prevalent in your facility? Do you have measures in place to combat these emissions?

APPENDIX C: WASTEWATER TREATMENT SURVEY

The assessment of wastewater management processes within the fruit and vegetable processing industry needs to be approached on a case-to-case basis. This is due the fact that facilities make use of different processes in order to produce their final product. This means that the volumes and quality of the wastewater would differ to varying degrees. Furthermore, different treatment processes are applied. This may be due to the fact that the facilities dispose of their final effluent in different ways; thus, their treatment requirements are different.

In order to successfully evaluate a facility's wastewater management process, certain aspects need to be in place. A monitoring system is required in order to determine some key values. Values that need to be monitored on a regular basis consist of the following: water intake volumes, effluent volumes as well as wastewater quality (COD, TSS and pH). One should also take into consideration what the facility's intention for the final effluent is, as this would influence which targets should be met. Thereafter, one can determine whether the targets are being met. If not, an investigation may be conducted in order to determine which part of the process is lacking in effectiveness. Once the faulty component is identified, one can determine whether an upgrade is needed or whether a different, more effective process should be applied.

The questionnaire for information gathering is shown below.

1) General Information

(1) Name of person completing survey
(2) Position in company
(3) What is the main nature of the facility? (juicing, canning, etc.)
(4) Please provide the name of the municipality responsible for monitoring your facility.

2) Seasonality

(1) Is the production process seasonal? If so, over which months does the season extend?

3) Production

(1) What are your main raw product inputs, and how many tons of each fruit or vegetable are produced annually?

4) Water Usage

(1) Please provide your total annual and daily water consumption, and indicate the primary source of the water? (municipal, borehole, river, dam)
(2) What is the unit cost (ZAR/kL) of water input?
(3) Is any additional treatment applied to incoming water before use? If so, please describe.
(4) If known, please provide specific water volumes per kilogram or per ton of final product produced.
(5) Where is water used in your production process? Please describe and give approximate percentage consumption for each of the production processes in relation to total usage. If possible, please provide a process flow diagram indicating consumption percentages.

5) Wastewater generation and management

(1) What is your total estimated annual and daily effluent volume? Please provide estimated percentages of the origin of effluent streams that make up the total effluent volume. If possible, please provide a flow diagram with relevant percentages.
(2) What treatment does the effluent undergo before discharge?
- Primary (please describe)
- Secondary (please describe)
- Tertiary (lease describe)
- Other (please describe)

(3) What happens to the discharged water? (e.g. irrigation, reuse, municipal sewage treatment plants, etc.)
(4) If discharge is sent to municipal sewage treatment plants, please provide the formula used in the municipality's by-laws to determine tariffs.
(5) Which wastewater quality parameters are routinely monitored? Please differentiate which parameters are monitored by the municipality and which are monitored by the industry.
(6) Are wastewater quality and quantity targets in place? If so, to what extent are these targets being met? If not, which water quality parameters are exceeding the discharge limits?
(7) Are wastewater monitoring routines in place? If so, please provide details.
(8) Are any of the wastewater or effluent streams reused? Please provide details of reuse and volumes.
(9) Do you think that there is scope for further beneficiation using any effluent streams? Please elaborate.

6) Solid waste/ slurry generation

(1) What is the type and quantity of solid waste or slurry generated per unit final product produced?
(2) Does the fruit and vegetable processing process produce any potentially toxic by-products?
(3) How is the solid waste currently disposed of?
(4) Do you think that there is scope for further beneficiation using any of the solid waste? Please elaborate.

7) Energy Usage

(1) What are your energy sources? Please select
- Boiler
- Grid (municipal electricity supply)
- Solar
- Biogas from wastewater

(2) What is your total energy use (kWh) in your production processes per day and per annum? Please indicate per product if available.
(3) What is the unit cost (ZAR/kWh) of energy used?
(4) Which gaseous emissions are prevalent in your facility? Do you have measures in place to combat these emissions?