

Pollutant loads of dairy effluent and its potential on pig growth performance

By

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Declaration

I, Nhalakanipho Wellcome Sithole, declare that this dissertation has not been submitted to any university and that it is my original work conducted under the supervision of Prof. M. Chimonyo and Prof. I. V. Nsahlai. All assistance towards the production of this work and all the references contained herein have been duly credited.

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List of Abbreviations

ADFI	Average daily feed intake
ADWI	Average daily water intake
ASB	Anaerobic sludge blanket
BOD	Biochemical oxygen demand
BWG	Body weight gain
COD	Chemical oxygen demand
CSIR	Council for Science & Industrial Research
CW	Constructed wetland
DAFF	Department of Agriculture, Forestry and Fisheries
DM	Dry matter
DWAF	Department of Water Affairs
FAO	Food Agriculture Organization of the United Nations
FCR	Feed conversion efficiency
FI	Feed intake
GDP	Gross domestic products
HTST	High-temperature short-time
ISO	International Standard organization
IWMI	International Water Management Institute
KG	kilograms
KL	kilolitres
MBR	Membrane bioreactors

MJ	Mega joules
NH ₄	Ammonia
NO ₂	Nitrogen dioxide
NO ₃	Nitrate
NRC	National Research Council
NTU	Nephelometric turbidity units
PO ₄	Phosphate
RBC	Rotational biological constructor
SAS	Statistical Analysis System
SBR	Sequencing batch reactor
SE	Standard error
TDS	Total dissolved solids
THMs	Trihalomethanes
TSS	Total suspended solids
WI	Water intake

Abstract

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The broad objective of the study was to determine pollutant loads in dairy effluent and assess its potential in feeding growing pigs. The first specific objective was to assess water utilization and conservation methods used by dairy processing plants. A structured questionnaire was administered to 233 companies and 103 enterprises responded. The idea was to determine water conservation strategies used in dairy processing plants and their level of water consumption. The size of the company on waste water generation and the treatment method used were captured. Water use on different processes was high ($P < 0.05$) in large companies and low ($P < 0.05$) in small companies. Water conservation strategies used were influenced ($P < 0.05$) by period of operation of the company. The size of the company, location and period of operation did not affect ($P > 0.05$) water source and water treatment used by companies.

To assess the pollutant loads generated by the different sizes of companies, a total of 150 dairy effluent samples were collected from dairy processing plants. These sample were obtained from small ($n = 10$); medium ($n = 10$) and large scale ($n = 10$) companies. Sources of effluents collected included wash equipment (milk tanks, pasteurizer and vats), effluents from different products (cheese, milk, yoghurt, fruit juices and sour milk), machine cooling effluent, effluent mixture before treating and effluent mixture after treating. The samples were collected from KwaZulu-Natal, Gauteng, Western Cape, Free State and Limpopo provinces using a sterilized 1ℓ plastic bottle and 150 ml plastic beaker (for coliform) and stored at $5 \pm 1^{\circ}\text{C}$. The effluents were analysed for

chemical oxygen demand (COD), suspended solids, nitrate/nitrite, chloride, sulphate and fluoride concentrations, colour, dissolved calcium, dissolved magnesium, pH, total dissolved solids (TDS), total hardness, turbidity and total coliform counts. The location of the company did not affect ($P>0.05$) pollutant loads except for fluorides ($P<0.05$). The size of company had high impact ($P<0.001$) on pollutant loads except ($P>0.05$) in sulphate concentration. Pollutant loads were also highly affected ($P<0.001$) by the type of product. The pH and concentrations of suspended solids and fluorides were not influenced ($P>0.05$) by water treatment. Effluent generated from washing equipment, products and pasteurizer cooling machine were affected by size of company and type of products but not the location of the company. The high volumes and concentration of effluents from washing of tanks lead to exploring the potential of using the effluent in feeding growing pigs. Objective 3 was, therefore, designed to compare the growth performance of pigs fed on dairy effluent from washing tanks.

Seventy two weaned male Landrace x Large White pigs housed in individual cages were randomly assigned to treatments. Half of the pigs were fed on dairy effluent, while the remainder received regular reservoir water. Average water intake (ADWI) (2.48 ± 1.21 l/d), average daily feed intake (ADFI) (1.03 ± 0.31 kg/d), average daily gain (ADG) (0.53 ± 0.39 kg/d) and feed conversion ratio (FCR) (2.5 ± 0.27) were not affected ($P>0.05$) by water source. The ratio of water intake (WI) to feed intake (FI) (2.4 ± 0.72) and ratio of water intake (WI) to body weight gain (BWG) (0.8 ± 0.2) was similar between the two treatments ($P>0.05$). The use of dairy effluent to feeding pigs could, therefore, save fresh water use.

Key words: size of company, performance, products, water intake, water source.

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Dedication

I dedicate this dissertation to my late granny Irene Nqobile Madela Sithole, mom Fikile Cynthia Masondo Sithole and aunt Zodwa Sithole Makhathini. These wonderful people could, unfortunately not live long enough to taste the fruits of their love.

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Chapter 1: General Introduction

1.1 Background

Water shortage globally is becoming a major concern. South Africa specifically is regarded as one of the countries currently facing serious water shortages crisis (Ndambi *et al.*, 2007). This is due to climate change, water pollution and increase in human population. Most of the fresh water is used for agricultural purposes (Department of Water Affairs (DWA), 2012). One other sector that uses high volume of water in South Africa is the dairy industry, consuming about 5 million m³ of water per year, of which 75 to 95 % of that water intake is discharged as effluent (Water Research Commission (WRC), 1989; Briao and Granhen Tavares, 2007). Therefore, producing dairy products under hygienic conditions could be essential in order to discharge less effluent. By 2050, the demand for water in the dairy industry is expected to double (van Borman, 2009), thereby exacerbating the competition for water between humans and the dairy sector. The competition will, consequently, have adverse impact on resource-poor households.

Water in the dairy industry is used during the processing of products, cleaning of office sale area and garage area (Carawan *et al.*, 1979a; WRC, 1989). The most consuming area of water is products processing and garage area (Carawan *et al.*, 1979a). In product processing, water is used during pasteurization, production of different products such as dry products (cheese, milk powder and butter); cultured products (yoghurt and dry fruits); liquid products (milk, fruit juices, and fruit juice blends) and cleaning, which is the most water consuming phase (WRC, 1989). In the garage, washing of crakes, truck milk tanks and floors are common activities performed. The effluent generated thereafter, is released either to municipalities or into nearby rivers.

Effluents generated from dairy processing plants vary in their organic pollutant loads (Briao and Granhen Tavares, 2007; Singh *et al.*, 2014). The chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), concentrations of nitrates, chlorides, fluorides and sulphates, dissolved calcium, dissolved magnesium, total dissolved solids (TDS), colour, pH, total hardness, turbidity (nephelometric turbidity units (NTU)) and total coliforms are common indicators of water quality (WRC, 1989; Strydom *et al.*, 1997; Winward *et al.*, 2008). The pollutant loads vary due to different types of products, type of equipment used and size of company (Food Agriculture Organization (FAO), 1996). Identifying effluents with low pollutant loads could be beneficial in determining recycling and re-use of the waste water so that the wastes lost to municipality sewer systems and rivers are reduced.

The possible use of dairy effluents so as to recycle and conserve water could be in feeding livestock and irrigation. Due to contamination of ground water and soil nutrients by organic material, bacteria and virus which could be associated with the use of dairy effluent during irrigation (Bedient *et al.*, 1984; Esterhuizen, 2012); irrigation then becomes less valuable. The use of dairy effluents for livestock drinking becomes the most ideal one. The ability of pigs to be tolerant on some pollutant loads including nitrate/nitrite (van Heugten, 2000), and chemical oxygen demand (COD) levels (Meek, 1996; National Research Council (NRC), 1998) makes them to be suitable animals to study the effect of waste water on performance. Some studies has also revealed little adverse effect has on pig performance when fed waste water (Veenhuizen *et al.*, 1992; Nyachoti *et al.*, 2005). This conclude the use of waste water on pigs to be ideal practise to conserve water. Studying, however, the effect of dairy effluent with low pollutant loads on pigs performance is highly essential so as to develop new water conservation strategies other than cleaner production (strategy that minimises waste and maximise product output), water pinch (strategy that promote the reduction of waste

water and fresh water usage) and water foot printing (strategy that measures total quantity of fresh water used in production of a single production of a single product consumed by the community) (DWAF, 2012).

1.2 Justification

Water has no substitute. The dairy industry is the largest consumer of water and should come up with technologies or methods of conserving water (Ndambi *et al.*, 2007). Demand for dairy products is on the increase. The understanding of pollutant loads of dairy effluents assists in the development of technologies to recycle and conserve water. Such interventions will reduce waste water generation and the utilisation of fresh water in the dairy industry. The reduction of competition for water between the industry and humans will results, thereby reducing costs of water and improving the livelihoods for the poor.

1.3 Objectives

The broad objective of the study was to assess pollutant loads of dairy effluents and explore the use of waste water in feeding growing pigs. The specific objectives were to:

1. assess level of awareness on water conservation across different sizes of dairy industries;
2. compare the effect of size of company and types of dairy products on pollutant loads; and
3. determine the effect of dairy effluent on pigs performance obtained from washing tanks.

1.4 Hypotheses

The hypotheses tested were that:

1. Water usage across different sizes of companies is the same, and dairy processing plants do not conserve water;
2. The size of company and type of products does not affect pollutant loads of dairy effluents; and
3. Using dairy effluent does not reduce the performance of growing pigs.

1.5 References

- Bedient, P. B., Rodgers, A. C., Bouvette, T. C., Tomson, M. B. and Wang, T. H., 1984. Groundwater quality at a creostote waste site. *Groundwater*, 22: 318-329.
- Briao, V. B. and Granhen Tavares, C. R., 2007. Effluent generated by the dairy industry: preventive attitudes and opportunities. *Brazilian Journal of Chemical Engineering*, 24: 487 – 479.
- Carawan, R. E., Jones, V. A. and Hansen, A. P., 1979a. Water use in a multiproduct dairy. *Journal of Dairy Science*, 65: 1238-1242.
- Department of Water Affairs (DWAF), 2012. Overview of the South African Water Sector. Pretoria, Republic of South Africa.
- Esterhuizen, L., Fossey, A. and Lues, J. F. R., 2012. Dairy farm borehole water quality in the greater Mangaung region of the Free State Province, South Africa. *Water SA*, 38: 803 - 806.
- Food Agriculture Organization of United Nations (FAO), 1996. Management of Waste from Animal Product Processing. Available at:
<http://www.fao.org/WAIRDOCS/LEAD/X6114E/X6114E00.HTM>. Date Accessed.[2013/08/11].
- Meek, A. J., 1996. Water quality concerns for swine. *Small Farm Today*. 13:15.

National Research Council, 1998. Nutrient Requirements of Swine (10th ed.).National Academy Press, Washington, DC, United States of America.

Ndambi, O. A., Hemme, T. and Latacs-Lohmann, U., 2007. Dairying in Africa-Status and recent developments. *Livestock Research for Rural Development*, 19.

Nyachoti, C. M., Patience, J. F. and Seddon, I. R., 2005. Effect of water source (ground versus surface) and treatment on nursery pig performance. *Canadian Journal of Animal Science*, 85: 405-407.

Singh, N. B., Singh, R. and Imam, M. M., 2014. Waste water management in dairy industry: pollution abatement and Preventive attitudes. *International Journal of Science Environment*, 3: 672 – 683.

Strydom, J. P., Britz, T. J. and Mostert, J. F., 1997. Two- phase anaerobic digestion of three different dairy effluents using a hybrid bioreactor. *Water SA*, 23: 151- 156.

van Borman, T. 2009. Agriculture: Fact and Trends South Africa. Available
http://awsassets.wwf.org.za/downloads/facts_brochure_mockup_04_b.pdf.
Date Accessed.|2013/04/09|

van Heugten, E., 2000. Guidelines for water quality in pigs. *Animal Science Facts: Extension Swine Husbandry*. ANS, 00-811S.

Veenhuizen, M. F., Shurson, G. C. and Kohler, E. M., 1992. Effect of concentration and source of sulfate on nursery pig performance and health. *Journal of American Veterinary Medical Association*. 201: 1203-8.

Water Research Commission (WRC), 1989. Water and Waste-Water Management in the Dairy Industry. WRC Project no 145 TT 38/89. NATSURV series no, 4. Published by the WRC, Pretoria, South Africa.

Winward, G. P., Avery, L. M., Stephenson, T. and Jefferson, B., 2008. Chlorine disinfection of grey water for reuse: Effect of organics and particles. *Water Research* 42: 483-491.

Chapter 2: Literature Review

2.1 Introduction

The global threats of climate change, increase in population and water pollution are of concern. These threats, among others, have a huge bearing on the capacity of municipalities to supply clean and safe water to the population. In South Africa, for example, agriculture receives about 60 % of the total water available to the country while contributing 4 % to the country's gross domestic products (GDP) (Department of Water Affairs (DWA), 2012). Of the 60 %, the largest portion goes to the crop production and dairy industry (Council for Science and Industrial Research (CSIR), 2010). Between 75 and 95 % of the water intake is discharged as effluent (Water Research Commission (WRC), 1989). There is need to document the water used in the dairy industry and develop strategies of conserving water and recycling the effluents that are generated.

Therefore, this chapter aims to review water conservation used by dairy processing plants, quality of effluents generated by companies and use of dairy effluent on pigs. The review will also look at water crisis and it causes paying attention to South Africa as an example due to its high risk of water scarcity, usage of water in dairy industry and the use of dairy effluent to conserve water.

2.2 The global water crisis

The global threat to water shortage is mainly global warming (CSIR, 2010). The activities performed lead to release of gases such as methane that reduces ozone layer (layer that reduces sun wave length). Depletion of ozone layer result in higher temperatures thus less rainfall is received. Factors causing water shortage are water pollution, population growth and climate change (CSIR, 2010). Currently South Africa, for example, has 49 200 million m³ per year total surface water

available, of which 4 800 million m³ comes from Lesotho (DWAF, 2012). The water is used for agricultural, environmental, urban and domestic, mining and industrial purposes (Table 2.1). The consequence of this is shortage of fresh water availability, which can have a huge impact on human welfare. The global demand for fresh water is also expected to exceed water that is available (DWAF, 2012). Currently, the competition for water between humans and livestock industries is already putting threats to water availability. Therefore, water use should be controlled. Possible measures include reducing pollution and the impact of climate change.

Increases in the demand for dairy products also threaten water availability. The increase in demand for milk due to increase in population is increasing pressure on milk producers hence the price for milk has also increased (DAFF, 2012). Due to high demand of milk products, water use also increases, thus reducing water availability, hence the practice of re-using water has to be improved. The contamination by irrigating with dairy effluent on pasture has caused dairy processing plant to shift from using borehole water to municipal water in order to avoid decreasing of dairy product quality (Esterhuizen *et al.*, 2012). Municipal water is treated therefore, it is expensive thus its revenue per year increases subsequently causing increases in the prices of dairy products (Eberhard, 2003).

The major cause of water shortage is pollution and climate change (CSIR, 2010). Companies release effluent to rivers which pollute water leading to reduction of fresh water. The increased demand of water by an increased population, leads to reduced water availability, moreover, dairy industries requires and use high volumes of water to process products (Carawan *et al.*, 1979a; WRC, 1989). This cause competition of water from humans and industries. The gases that are

Table 2.1: Water use in South Africa

Water usage	%
Agricultural use (including irrigation)	60.0
Environmental use	18.0
Urban and domestic use	11.5
Mining and industrial use	10.5

Source: DWAF (2012)

released by companies that deplete ozone layer, also lead to dramatic climate change (CSIR, 2010). This consequently reduce rainfall received.

2.2.1 Pollution

Pollution is a contamination of environment by toxic substances. Pollution threatens the environment causing a disturbance on the normal functioning of the environment. Types of pollution include air pollution, water pollution and soil pollution. The mostly provoked pollution type by dairy is water pollution. Water pollution is mostly caused by salinization, eutrophication, disease-causing micro-organisms and acidification (CSIR, 2010).

2.2.1.1 Salinization

Salinization is a process that increases the salinity (dissolved salt content in water) of water; it could be natural or man-made (Higgins *et al.*, 2008; CSIR, 2010). The most contributing factor to increased salinity in rivers is the disposal of industrial effluent (WRC, 1989). This is where dairy industries could be culprits because they release effluents that cause salinity. These effluents consist mainly of salts such as sodium, magnesium, nitrates, phosphates and calcium compounds, of which some come from detergents and others from acidic whey (van Rensburg *et al.*, 2008; Li *et al.*, 2009). Salinity is a challenge in that if water has been exposed to salt coming from industries for a prolonged period, it becomes difficult to control that water back to its normal level (Oberholster *et al.*, 2008). Pollution of the Vaal and Orange Rivers, which are some of the biggest in South Africa, threatens economic development. Pollution reduces crop yield (CSIR, 2010), and hence food security status of the country, particularly among the poor. In the dairy sector, reduction in pasture quality results in huge losses in milk production. Human health is also put at risk, since the prevalence of diseases such as methaemoglobanaemia, bone and dental fluorosis increase due to

high concentrations of nitrate and fluoride in water (CSIR, 2010). Another consequence of effluent discharge is eutrophication.

2.2.1.2 Eutrophication

Eutrophication is a process whereby excessive growth of algae and other aquatic plants is encouraged as a result of the enrichment of water with plant nutrients, particularly nitrogen and phosphate forms (NO_2 , NO_3 , NH_4 and PO_4) (CSIR, 2010). In Africa, 28 % of lakes have undergone eutrophication (Nyenje *et al.*, 2010). In South Africa, these include Zeekoevlei (Das *et al.*, 2008), Rietvlei (Oberholster *et al.*, 2008) and Lake Krugersdrift (Oberholster *et al.*, 2009a). Effluents released from the dairy sector are organics, nitrates, phosphates, potassium and suspended solids (WRC, 1989). Their high concentration on rivers or lakes supports the growth of cyanobacteria *Microcystis* and *Anabaena* (van Ginkel, 2004). Inorganic fertiliser from crop farming and effluents from the dairy industry are the biggest culprits releasing enough nutrients that cause eutrophication (Jarvie *et al.*, 2006). Bacteria convert nitrogen from proteins into inorganic form such as nitrates, ammonia and ammonium which then leads to eutrophication (Walker *et al.*, 2000; Barnett *et al.*, 2012).

2.2.1.3 Disease-causing micro-organisms

Cyanobacteria (blue water algae) cause water purification problems to an extent that it discolours water thus causing an unpleasant smell and bad taste (CSIR, 2010). Cleaning the water leads to increased purification costs as algae would likely block the filters. Water treatment processes used in South Africa are flocculation, sedimentation and sand filtration (CSIR, 2010). All these methods are not appropriate to expel cyanobacterial bio-toxins in water. Reservoirs which are at high-risk in South Africa include Roodeplaat and Rietvlei in Gauteng; Loskop Dam in Mpumalanga, Smith

Dam in KwaZulu-Natal, Bridle Drift and Laing in the Eastern Cape; Voëlvlei Dam in the Western Cape; and Hartbeespoort and Klipvoor Dam in North West (CSIR, 2010). These reservoirs also have high levels of disease-causing micro-organisms, putting human health at risk.

The dairy industry release effluents that go into streams, lakes, reservoirs and rivers adding onto the adverse impact or effects of diseases causing organisms. These effluents are high in bacteria, viruses and protozoa. The presence of *Legionella pneumophila* in waste water has been reported (Casanova *et al.*, 2001; Birks *et al.*, 2004). It is naturally resistant to water treatment processes and is inhalable. Therefore effluent to be discharged from dairy industry should be treated first before these bacteria accumulate in rivers. Other bacteria include coliforms, *Escherichia coli*, *Campylobacter* and *Enterococci* (Winward *et al.*, 2008). These, in turn, cause diseases such as cholera and Salmonellosis (Momba *et al.*, 2004). In South Africa, diarrhoea cause about 10 % of the deaths in children under the age of five years and is the third highest cause of deaths for children at this age (CSIR, 2010).

2.2.1.4 Acidification

Acidification is another problem that persist in rivers (CSIR, 2010), largely due to extensive mining. These mines highly contaminate ground water with acidic metals and release ground water to the streams. Dairy effluents also play a role in acidifying rivers, although at a lower proportion as compared to mining. Most dairy industries release effluents which are slightly acidic. Strydom *et al.* (1997) reported that cheese factories can be blamed for releasing effluents with pH of 5.2 followed by milk powder/butter factory with a pH of 5.8. Proper effluent treatment should, therefore, be conducted before releasing the grey water into rivers.

2.2.2 Climate change

Greenhouse gases which are harmful to the atmosphere include carbon, nitrogen and sulphur emission (CSIR, 2010). These gases are emitted from “boiler stack (vertical pipe which release gases from boiler to outside environment) during processing of dairy products, denitrification process and volatilization of ammonia from urine and dung patches (CSIR, 2010; Barnett *et al.*, 2012). The formation of ammonia and nitrogen oxides (NO_x) from nitrogen leads to climate change and global warming (Pinder *et al.*, 2012). Nitrous oxide, apart from being a global-warming threat, reduces the ozone layer in the stratosphere (Ravishankara, 2009). Methane also causes climate change. Methane is emitted from ruminant fermentation (CSIR, 2010). Manure also emits methane.

2.3 Competition for water between humans and manufacturing industries

Competition for fresh water between humans and manufacturing industries is highly caused by increase in population growth and high water use in dairy industries. Increase in population growth put threats to demand for dairy products. This forces companies to increase productivity due to high demand. This however, results in increased water usage by companies. An increase in water usage by companies is likely to reduce water availability for humans. Municipalities are then forced to increase water rates so as to supply for every one thus maintaining competition of water.

Africa is one of the leading continents with high population growth. In South Africa, the population grew from about 20 million in 1994, to 50 million people in 2012 (Statistics South Africa (STATSSA), 2013a). This could be linked with teenage pregnancy, unemployment and migration. The unemployment rate in South Africa is 24.1% (STATSSA, 2013b). Since many people are not working, the chances of sexual activity becomes the possible activity to increase population. The migration of people from neighbouring countries to seek for employment in South Africa also cause

population growth. Some people migrate from rural areas e.g. Eastern Cape, Free State and Limpopo into cities to seek employment (STATSSA, 2013b). Municipalities are the biggest supplier of water in cities (Eberhard, 2003). This creates pressure within the municipality to balance water supply between industries and residential areas. There are instances where residents also use water without paying to the municipalities (Saving Water SA, 2011). As a result, water costs increase. The increase of population, also increases energy demand for lighting, cooking, bathing and ironing is also increasing. South African energy comes from burning of coal in power stations (Groenewald, 2012). The end result of this is a release of sulphur and nitrogen oxides emissions into the atmosphere. Acid rain result due to the release of these two gases (CSIR, 2010).

Human growth population is highly influenced by teenage pregnancy in South Africa (Ross *et al.*, 1983a). An increase in population growth poses increases on the demand for milk and milk products. One of the major reasons for demand of milk is feeding infants. Ross *et al.* (1983a) reported that 72 % of infants feed on formula milk at an age of between one and five weeks. There are many reasons to explain as why most women no longer prefer to breast-feed. Most women of today are professionals and some are at school and some do not get maternity leave (Ross *et al.*, 1983a). The high prevalence of HIV also forces women not to breast-feed (Table 2.2). These factors increase in demand for milk products (formula milk). Increase in demand of milk and milk product is responsible for an increase in the demand for water by the dairy industry.

2.4 Uses of water in the dairy industry

In dairy industry uses of water is divided into three different segments namely: office sales area, garage area and processing area. The processing area consumes the most water followed by the

Table 2.2: Reasons for discontinuing breast-feeding

Reason	Percentage	Source
Not enough milk	54	Ross <i>et al.</i> (1983a)
Baby not satisfied	32	Ross <i>et al.</i> (1983b)
Returning to work	22	Ross <i>et al.</i> (1983b)

garage area (Carawan *et al.*, 1979a; Table 2.3). The processing area produces different products, while in the garage cleaning of trucks and washing of milk tanks takes place.

2.4.1 Office-sales area

Office sale area includes the kitchen, toilet and showers. It is the least water consuming area within the industry. Leakage of water taps, over using by showers and cleaning the place are most water consuming factors. As expected, the office sales area is the one with the least pollutant loads while processing area has the highest (Chaillou *et al.*, 2011). The pH ranges from acidic to alkaline; while in office sale area, pH and COD values are around normal standards for clean water. The acidic whey from cheese, for example, increases phosphate concentrations in rivers if water released without treatment, thereby causing eutrophication (WRC, 1989).

2.4.2 Garage area

Within the plant, the garage forms the second largest water consuming sector (Table 2.4). Activities done here includes the washing of crakes, truck milk tanks and floor. Over application of water when washing is a common problem which mostly occurs at this area, due to equipment malfunctions and worker carelessness (Carawan *et al.*, 1979a). Washing time of truck tanks is every after delivery while crates washing is often seen during peak hours of productivity and late hours. After every delivery, a hot rinse (35 – 43°C) is applied firstly and rinse until water turns clear, then a second rinse is applied with an alkaline solution then lastly is an acidic rinse with hot temperature (35 – 43°C) (WRC, 1989). During the washing of crates and bottles, firstly a cold pre rinse is applied which goes to the drain then a second hot with detergent wash is applied which also goes to the drain then lastly a final cold or warm rinse which could be used for the first rinse in next cycle take place (WRC, 1989).

Table 2.3: Plant water use by areas

Area	Water use/total product (kg/kg)
Garage	0.09
Office complex	0.03
Processing plant	3.57

Source: Carawan *et al.* (1979a)

Table 2.4: Comparison between office sales area and processing area pollutant loads

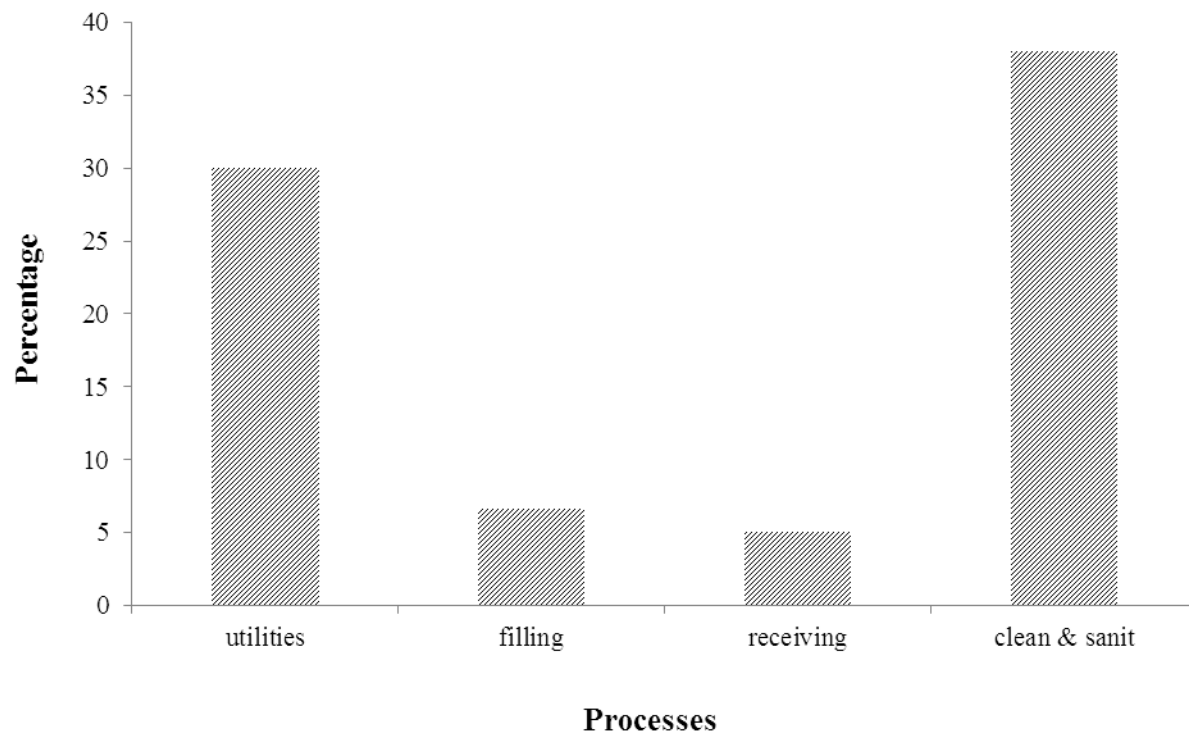
Source	pH	COD mg/l	Source
Office sale	6.15-7.75	63-1341.5	Li <i>et al.</i> (2009)
Processing plant	2.2-11.8	1908-5340	Strydom <i>et al.</i> (1997)

COD – Chemical Oxygen Demand

Bottle or crate washing and milk truck tankers (under receiving) consume a lot of water (Figure 2.1). This may be due to over-washing which is caused by insufficient training of the employees, carelessness and leakages. Efficient management is, therefore, required to monitor the use of water (Carawan *et al.*, 1979a). Where no bottles are used, water could be saved. Such investigations need to be made in the South African dairy industry. As expected, cleaning-in-place accounts for the biggest portion for water consumption (38%). Thorough cleaning is meant to avoid contamination by bacteria of dairy products.

2.4.3 Processing area

The processing area is the largest consuming sector for water within the dairy industry plant (Table 2.4). Consumption of water is calculated as the kg of water (1ℓ = 1kg) per total kg of product (Carawan *et al.*, 1979a). Processing include many different fields such as cultured products (buttermilk, maas, yoghurt and drinking yoghurt), dry products (cheese, full cream, low fat, skim milk powder, whey powder, butter, ice cream and condensed milk), fruit juices and pasteurized milk (Figure 2.2). During processing, the most consumable time for water is from 0700h to 1400h because those are peak times for production (Figure 2.3). Maximum water consumption is also observed around late afternoon (1500-1600h), and this is due to cleaning-in-place which takes place.



Source: Carawan *et al.* (1979a)

Figure 2.1: Percentage of water use for selected processes

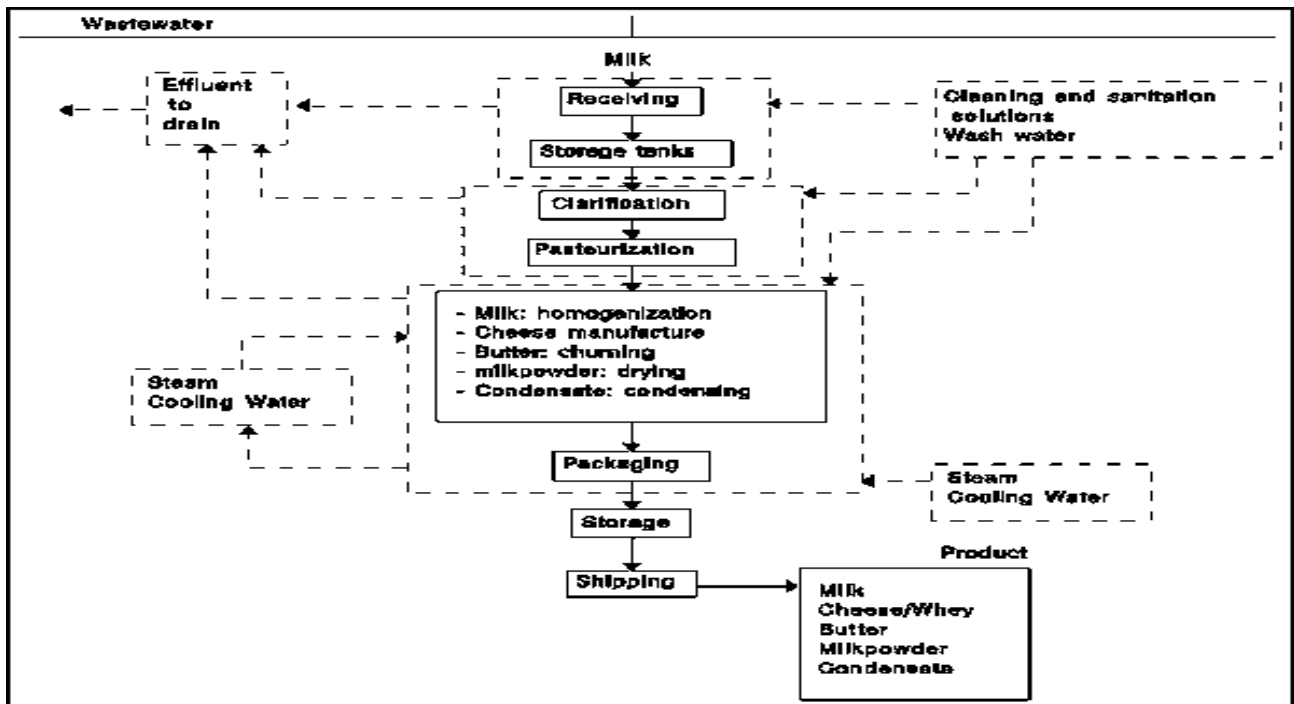


Figure 2.2: Schematic flow diagram of water use in processing plant (Adapted from FAO, 1996)

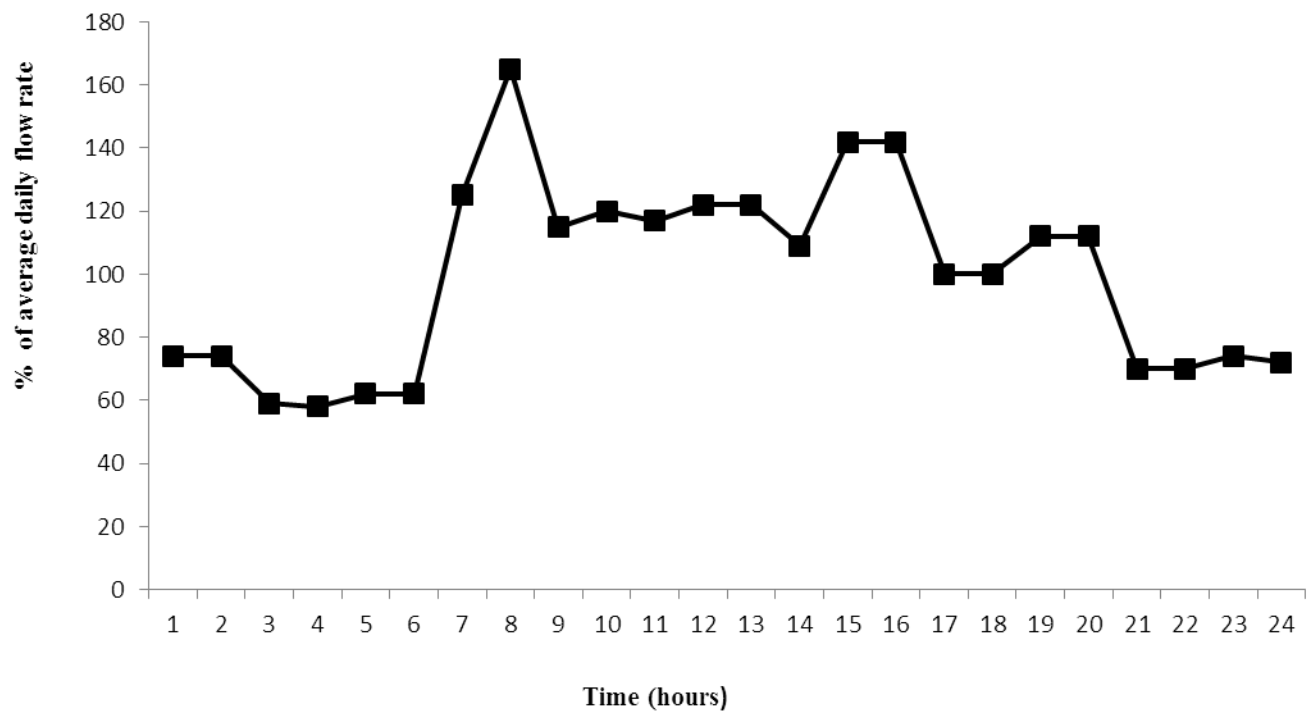


Figure 2.3: Hourly water use in dairy plants (Adapted from Carawan *et al.*, 1979a)

2.4.3.1 Cultured products

Cultured products are made from certain cultures and incubated at specific temperatures. Milk is pasteurized in hot water (80-85°C) for about 30 minute destruct harmful bacteria before it is cooled to 40 - 45°C using cold water (Food Agriculture organization (FAO), 2013a). This is where high amounts of water (depending on size of company and type of product) are used during boiling and cooling (WRC, 1989). Milk is then incubated for 2-3 hours with starter culture at the same temperature (40-45°C), at a pH of about 4. Then the product is chilled to stop the growth of bacteria (WRC, 1989). Thereafter, the product is cooled at a temperature below 8°C; this same procedure is followed for sour milk production but with slightly longer step (12-20 hours) incubation than yoghurt. The availability of nutrients (vitamin B-2, B-12, potassium, magnesium and calcium) and beneficial bacteria (probiotics) contained in cultured products are likely to cause an increase in demand of cultured products (Magee, 2005). This will subsequently increase water demand since high amount are required for pasteurization. Milk demand will be increased due to production of cultured products which will have ability to address food insecurity due to nutrients availability.

2.4.3.2 Dry products

Dry product operations are the second largest water-consuming operations within the processing plant. In a comparison between cheese factory and milk powder/ butter factory (Table 2.5), cheese factory consume more water (495 kℓ. d⁻¹) than butter (390 kℓ. d⁻¹). This is because in the butter factory, cream from milk after standardization is used as the raw material, which is then mixed with salt and placed on a continuous churn (WRC, 1989). Thereafter, the cream is separated into butter and buttermilk, which then get extruded continuously until the final product emerges. During cheese production, on the other hand, after standardization and pasteurization, milk is added with

Table 2.5: Comparison of type of product on water usage and effluents

Parameter	Cheese	Fresh milk	Milk powder/butter
pH	5.22	6.92	5.80
COD (mg.ℓ ⁻¹)	5 340	4656	1908
Water usage (kl.d ⁻¹)	495	682	390
Milk usage (kl.d ⁻¹)	168	223	86 [¶]
Specific water usage (ℓ.ℓ ⁻¹)	2.94	3.06	4.54

[¶]-Figure in tons of milk; COD- Chemical Oxygen Demand

Source: Strydom *et al.* (1997)

rennet and cultured to coagulate. Once milk coagulates, the curd is exposed to mechanical treatments, resulting in the separation of curd with whey. At the same time, the curd is treated with heat to lower the lactose content. This is done using the hot steam treatment or hot water treatment. That is why water consumption between the two factories (butter and cheese) differs. Once whey is drained off, the curd is moulded, salted and pressed.

Another dry product known to consume water is ice cream. Ice cream is defined as the product resulting from mixing of dairy ingredients (including different flavours and sugars), aerated and frozen (Clarke, 2006). During production of ice cream, cream, whey powder, butter milk powder and water are mixed. This is where water consumption takes place also. After the mixture is homogenized and pasteurized it is tested for ageing. Thereafter, the colouring, fruit and flavouring are included quickly before freezing (WRC, 1989). The mixture is then placed on a continuous freezer and gets packed in different volumes for retail. Carawan *et al.* (1979a) reported that the frozen product is one that consumes more water followed by by-product (Table 2.6). An explanation given to this is that the machine (Vitaline) used to produce new stick type ice cream uses about 28 % water to produce frozen product. The effect of season is also significant in influencing water consumption. Water used by the machine to process each product during the hot season was 8.5ℓ per dozen unit of product (Carawan *et al.*, 1979a). While in winter water use is less than 8.5ℓ due to low demand since it cold season (Carawan *et al.*, 1979a). This is a huge water use which could be minimized if skilled and proper management is applied. The current consumption patterns and volumes are largely unknown.

Table 2.6: Water for processing various products

Product	Water use/product (kg/kg)
Frozen product	15.7
By products	10.5
Fluid product	1.89

Source: Carawan *et al.* (1979a)

Condensed milk is produced in two different ways, namely sweetened condensed milk and unsweetened condensed milk (WRC, 1989). Most water for dry products is used during heating and cooling, hence some water is also lost by evaporation from the product. The difference between condensed milk and other dry products is the amount of water removed through the evaporation process. For condensed milk, about 65-70 % water is removed, while in other dry products, such as powdered milk, the amount of water lost exceeds those values (FAO, 1996). As for the other products, condensed milk get standardized, pasteurized and then heated to deactivate micro-organisms and stabilize the milk to avoid coagulation (WRC, 1989). All this requires water and energy, to apply during the processing of the product. Therefore, energy analysis also plays an important role when assessing water utilization in the dairy industry. After heat treatment, milk is treated differently. For unsweetened condensed milk, milk is concentrated through the evaporator then homogenized followed by cooling. In sweetened milk, sugar is added before cooling. For both products, cold water is used to cool the product.

2.4.3.3 Pasteurized milk

Pasteurized milk is processed through five steps namely raw milk reception, pasteurization, standardization and de-aeration (WRC, 1989). As shown in Table 2.5, milk production consumes more water ($682 \text{ k}\ell. \text{ d}^{-1}$) than any other products. Heating and cooling treatments require a huge amount of water for maintaining the quality of milk. To maintain hygiene, a lot of water is used to wash tanks for storage of milk. Thereafter, milk is pasteurised by boiling water ($85 - 90^{\circ}\text{C}$) to eliminate and de-activate bacteria as such increasing the shelf-life of pasteurized milk (WRC, 1989; Bille and Keya, 2002). Milk is then standardized to reduce excess fat in milk. Once unwanted gases are removed, homogenization is performed to distribute fat equally across the milk. This is achieved

by exploring milk “intensive shear forces to break up the fat globules” (WRC, 1989). The final step is cooling below 4°C which is then followed by packing.

2.5 Quality and quantity of dairy effluents from processing plants

Quality of dairy effluent is highly affected by type of products processed. Strydom *et al.* (1997) reported a chemical oxygen demand (COD) of 5 340 mg.ℓ⁻¹ from cheese product; 4 656 mg.ℓ⁻¹ from milk product and 1 908 mg.ℓ⁻¹ from milk powder or butterfat products. Ikhu- Omoregbe *et al.* (2001) reported an average of 3 300 mg.ℓ⁻¹ COD for milk and milk products. Water Research Commission (1989) reported COD for whole milk of 210 000 mg.ℓ⁻¹, skimmed milk 100 000 mg.ℓ⁻¹, butter milk 110 000 mg.ℓ⁻¹ and whey for 75 000 mg.ℓ⁻¹. Another factor is the size of the company (FAO, 1996). Water Research Commission (WRC) (1989) reported a 2000 mg/l COD for small companies. Ikhu- Omoregbe *et al.* (2001) reported a pH of 7.9 from large companies and 6.35 in small companies. The equipment's and products processed by companies also affect the volume of effluents. Small companies have been reported to produce 237 kl.y⁻¹ while large companies produced 20 250 kl.y⁻¹ of dairy effluent (Ikhu- Omoregbe *et al.*, 2001). Therefore, considering the factors affecting quality will assist in determining an adequate source of dairy effluent to use for animal feeding.

2.6 Ways of conserving water

Conserving water not only saves money but also reduce pollutant loads. Having high waste water and pollutant loads indicate that less product is being made while cost is increasing. This may be due to various reasons, including management. There are many ways of conserving and purifying water within the industry. This includes cleaner production, water pinch, water foot print management and dairy effluent use.

2.6.1 Cleaner production

Cleaner production is defined as a technique or practice that eliminates the use of hazardous substances “through the use of non-hazardous chemical”, minimize waste and maximize profit output (Thorpe, 2009). Cleaner production is integrated into four principles namely: the Preventive principle, the Public Participation Principle, and the Holistic Principle (Thorpe, 2009). All these principles emphasized taking action or using certain techniques as early as possible to avoid the impact which the dairy plant can have on the nature. Such impact includes the use of harmful detergents for cleaning which result in having high concentrations of elements in waste water which makes it hard to recycle the water. Therefore, using cheap and less harmful detergents could reduce the problem; hence less water is used for rinsing. Dairy plants that release waste water with untested chemicals should demonstrate the knowledge of their discharge and be proactive, rather than requiring regulators to show that the discharge is harmful (Thorpe, 2009). It is better to prevent damage early in the environment than to try to control or manage the impact later. This is because less money is used; more time is available to do proper planning to reduce polluting the environment.

2.6.2 Water pinch

Water pinch is a technology which analyses water networks and have the ability to reduce expenditures which has to do with processes using water differently (Ataei *et al.*, 2010). This technology focuses on savings financially within the industry. This is achieved by optimising activities work load for inputs such as electricity and water when they are applied at different locations of the plant and enables the balancing of their usage within the plant. “Pinch technology does this by making an inventory of all producers and consumers of these utilities and then systematically design an optimal scheme of utility exchange between these producers and

consumers” (Strauss, 2006). As this technology is able to reduce utilities using water differently, this means that fresh water usage is reduced hence cost as well. Having an ability to use fresh water less and promote the reuse of water within the industry, result in less effluent discharge into the environment. This also increases the water availability for use in the communities.

2.6.3 Capacity building

In dairy processing plant water is the largest consumed input as it is used for different processes such as for heating, cooling, washing, and cleaning up. Water use can be high due to poor management and or the type of the technology the plant uses (Rausch and Powell, 1997). Carawan *et al.* (1979a) suggested that one of the ways to reduce water use and effluent generation in dairy processing plant is to apply proper management, engineering practices and computer modelling to evaluate the impact of proposed changes within the processing plant. A conclusion made by Carawan *et al.* (1979a) is that proper management and improved technology or design could reduce water requirement that is required by the vitaline machine (machine used to produce new stick type ice cream). This occurred after they observe that vitaline machine used about 28% water in order to produce frozen product. Workers require proper management as not all staff is properly skilled within the industry (but depends on the dairy processing plant). Therefore, if improper management is used problems like over washing cases than required, spills, drip, malfunction of equipment and worker carelessness will result (Carawan *et al.*, 1979a). Many plants have successfully reduced water use to one gallon per gallon of milk used for processing and this has been achieved by implementing proper management. Therefore, to save water cost, water usage and effluence generation, it is important to consider management first. The extent of water conservation in the dairy plants in South Africa needs to be determined.

2.6.4 Using dairy effluent

Dairy effluent is waste water which is mainly generated from cleaning-in-place and food processing in dairy industry which excludes water from toilet (Carawan *et al.*, 1979a). Dairy effluent is the most reusable source thus it can substitute the use of fresh water in both dairy and swine industry. Dairy effluent can be used for irrigation, fed to livestock for drinking, and regulating temperature on poultry and pigs. Care should be taken when using dairy effluent in livestock as this can reduce performance and increase the spread of diseases.

2.6.4.1 Treatment of dairy effluent

Dairy effluent can be treated into three ways namely: physical, chemical and biological treatment (Li *et al.*, 2009). Physical treatment includes soil filtration, membrane filtration and coarse sand filtration. Chemical treatment includes chlorine treatment, coagulation, granular activated carbon, ion exchange and photo-catalytic oxidation. Biological treatment includes constructed wetland (CW), membrane bioreactors (MBR), rotating biological contractor (RBC), and anaerobic sludge blanket (UASB) and sequencing batch reactor (SBR) (Li *et al.*, 2009).

Physical treatment methods applied to dairy effluent includes soil filtration, coarse sand filtration and disinfection (boiling). Soil treatment helps to remove organic pollutants and total phosphorus. Due to natural reactions (nitrification and de-nitrification) which take place in the soil, nitrogen is reduced successfully in dairy effluent (Li *et al.*, 2009). The coarse sand treatment has less effect on reduction of pollutants if applied alone. March *et al.* (2004) observed a reduction of COD from 171 to 78 mg/ℓ, and the turbidity from 20 nephelometric turbidity units (NTU) to 16.5 NTU when a nylon sock filter, sedimentation and disinfection steps were used. Li *et al.* (2009) observed a little

effect of sand filter when it was combined with carbon and disinfection as 48 % of the suspended solids were removed and turbidity was reduced by 61 %. Pidou (2006), however, reported an adequate reduction of micro-organisms.

Chemical treatment includes chlorine treatment, coagulation, photo-catalytic oxidation, ion exchange and granular activated carbon (Li *et al.*, 2009). Chlorine disinfection methods have been widely used to disinfect both green and grey water. The mechanism behind the effect of chlorine in inactivating microorganisms is not yet understood (Winward, 2008). Virto *et al.* (2005) explained that the cell membrane of bacteria experiences a change in permeability once chlorine has been introduced. The membrane determines the extent to which the bacteria are susceptible or resistant to the chlorine effect. Another widely used method is coagulation. Li *et al.* (2009) reported a reduction in COD from 55 to 22mg/ℓ, the biological oxygen demand (BOD) from 23 to 9mg/ℓ, the turbidity from 43 to 4 NTU after electrocoagulation was used followed by a disinfection method. These results were also confirmed by Pidou *et al.* (2008).

Biological treatments include a variety of methods including rotational biological contactor (RBC) sequencing batch reactor (SBR), anaerobic sludge blanket (UASB), constructed wetland (CW) and membrane bioreactors (MBR) (Li *et al.*, 2009). A lot of work has been done on different types of biological treatments and all concluded with similar results. The most commonly found case is that biological treatment is followed by filtration steps, mainly sand filtration, then disinfection step follows so as to meet the standards (Li *et al.*, 2009). Friedler *et al.* (2005) reported a reduction in TSS 43 mg/ℓ -16 mg/ℓ, Turbidity 33 NTU-1.9 NTU, COD 158 mg/ℓ- 46 mg/ℓ, BOD 59 mg/ℓ- 6.6 mg/ℓ and faecal coliform $5.6 \times 10^5/100$ ml- $9.7 \times 10^3/100$ ml after they combine RBC, sand filtration

and chlorination. The result also corresponded to the result discovered by Nolde (1999) who used RBC in combination with ultra violet (UV) disinfection stage.

2.6.4.2 Uses of dairy effluent

Dairy effluent is and has been highly utilized in irrigation of pastures (Esterhuizen *et al.*, 2012); irrigation of lawns at college campuses, cemeteries and golf courses (Okun, 1997). This highly saves water for irrigation required on this site. Dairy effluent from dairy farms is high in micro-organisms or manure as they are exposed to cattle dung during washing of the floor. That water can be highly beneficial to crops farming, hence, dairy effluent contains some quantities of phosphorus and nitrogen which can benefit farmers with no manure or fertilizer (Eriksson *et al.*, 2002). The application of dairy effluent for irrigation in gardens as well as small scale agricultural sectors reduce fresh water demand; hence, this can also contribute to the food security status in rural settlement by the provision of nutritional water suited for irrigation of crops (Murphy, 2006, Rodda *et al.*, 2011). A saving on water decreases the cost of buying water. This also reduces waste water contamination to rivers and lakes which could reduce salinity, pollution and eutrophication. The use of dairy effluent for irrigation has adverse disadvantages somehow. Contamination of ground water and soil nutrients by organic material, bacteria and virus which could be associated with the use of dairy effluent during irrigation is likely to occur (Bedient *et al.*, 1984; WRC, 1989; Esterhuizen, 2012).

Dairy effluent used for toilet flushing can reduce up to 30% water demand (Karpiscak *et al.*, 1990). This reduces fresh water usage but increase work load on sewage treatment such that if heavy or poisonous substances are exposed, difficulty to retreat water may result. The use of dairy effluents for livestock becomes the most ideal one. In animal use, dairy effluent is mostly used in production

for broilers (WRC, 1989). In cheese production, whey can be used in broiler production (WRC, 1989). Whey is high in protein and biological value (BV); it is a supplement rich in proteins for livestock. Therefore, liquid whey and associated effluents become a saving on water within the dairy plant and a benefit for broiler feed production as a dairy effluent component. Due to high number of animals used for production, supplementing with dairy effluent particular whey, cannot be sufficient to accommodate all animals hence the rest of dairy effluents with low protein value but pollutant loads will be disposed.

The regulation of temperature on poultry using dairy effluent is a huge saving for grey water re-use. The use of dairy effluent for regulating temperature, however, is affected by season. During winter season, the use of dairy effluents could be less important in regulating temperature compare to summer season due to low temperatures. Therefore, the possible use of dairy effluents so as to recycle and conserve water could be feeding livestock. It is crucial for dairy effluent not to depress animal productivity. The ability of pigs to be tolerant on some pollutant loads including nitrate/nitrite (van Heugten, 2000), and chemical oxygen demand (COD) levels (Meek, 1996; National Research Council (NRC), 1998) makes pigs to be suitable animals to study the effect of waste water on performance. The acceptable levels of water quality for pigs are pH 6.5-8.5, TDS \leq 1000 ppm and hardness \leq 60 ppm (NRC 1998; Nyachoti and Kiarie, 2010). Some studies have revealed little effect on pig performance fed on waste water sliding from acceptable levels (Veenhuizen *et al.*, 1992; Nyachoti *et al.*, 2005). Anderson *et al.* (1994) reported that feeding pigs with water which has high levels of TDS does not reduce growth performance. Meek (1996) and National Research Council (NRC) (1998) reported that pigs can consume water with a total coli form (bacteria found in water) per 100 ml of 5000 CFU/ 100 ml. This concludes the use of waste

water on pigs to be ideal practise to conserve water. The issue of water analysis, therefore, plays an important role to assess the quality for dairy effluent so that proper application can be practised.

2.7 Summary

The dairy industry is in expanding to meet the increased demand for dairy products. The increase in the amount of milk processed leads to increases in the water usage and the resultant effluent that is generated. The issue of recycling waste water should, therefore, be prioritized. Research should focus on developing methods of conserving water, assessing pollutant loads and developing methods for recycling waste water from the dairy industry.

2.8 References

- Anderson, J. S., Anderson, D. M. and Murphy, J. M., 1994. The effect of water quality on nutrient availability for grower/finisher pigs. *Canadian Journal of Animal Science*, 74: 141-148.
- Ataei, A. and Yoo, C. K., 2010. Simultaneous energy and water optimization in multiple-contaminant Systems with flow rate changes consideration. *International Journal of Environmental Research*, 4: 11-26.
- Barnett, J. W., Robertson, S. L. and Russell, J. M., 2012. Environmental issues in dairy process. *Dairy Journal of Environment*, 3: 1-16.
- Bille, P. G. and Keya, E. I., 2002. A comparison of some properties of vat-heated and dry skimmed milk powder fortified set yoghurts. *Journal of Food Technology in Africa*, 21-23.
- Birks, R., Colbourne, J., Hills, S. and Hobson, R., 2004. Microbiological water quality in a large in building, water recycling facility. *Water Science Technology*, 50: 165–172.

- Carawan, R. E., Jones, V. A. and Hansen, A. P., 1979a. Water use in a multiproduct dairy. *Journal of Dairy Science*, 65: 1238-1242.
- Casanova, L.M., Gerba, C.P. and Karpiscak, M., 2001. Chemical and microbial characterization of household grey water. *Environmental Engineering Science*, 36: 395–401.
- Chaillou, K., Gérente, C., Andrès, Y. and Wolbert, D., 2011. Bathroom greywater characterization and potential treatments for reuse. *Water Air Soil Pollution*, 215: 31–42.
- Clarke, C., 2006. *The science of ice cream*. Cambridge, United Kingdom.
- Council for Science and Industrial Research (CSIR), 2010. A CSIR perspective on water in South Africa – 2010. Available at:
http://www.csir.co.za/nre/docs/CSIR%20Perspective%20on%20Water_2010.PDF.
 Date Accessed.|2013/07/09|
- Das, S. K., Routh, J., Roychoudhury A. N. and Klump, J. V., 2008. Elemental (C, N, H and P) and stable isotope ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) signatures in sediments from Zeekoevlei, South Africa: a record of human intervention in the lake. *Journal of Paleolimnology*, 39: 349- 60.
- Department of Agriculture, Forestry and Fisheries (DAFF), 2012. A profile of the South African dairy market value chain. Pretoria. South Africa.
- Department of Water Affairs (DWAF), 2012. Overview of South African water sector. Pretoria, Republic of South Africa.
- Eberhard, R. E., 2003. Administered prices water: A report for National Treasury. Department of National Treasury. Pretoria, South Africa.
- Eriksson, E., Auffarth, K., Henze, M. and Ledin, A., 2002. Characteristics of grey wastewater. *Urban Water*, 4: 85–104.

- Esterhuizen, L., Fossey, A. and Lues, J. F. R., 2012. Dairy farm borehole water quality in the greater Mangaung region of the Free State Province, South Africa. *Water SA*, 38: 803 - 806.
- Food Agriculture Organisation of United Nations (FAO), 1996. Management of waste from animal product processing. Available at:
<http://www.fao.org/WAIRDOCS/LEAD/X6114E/X6114E00.HTM>. Date Accessed. |2013/08/09|
- Food Agriculture Organisation of United Nations (FAO), 2013a. Production of cultured milk (Milk Processing Guide Series). FAO/TCP/KEN/6611 Project, 4.
- Friedler, E., Kovalio, R. and Galil, N. I., 2005. On-site greywater treatment and reuse in multi-storey buildings. *Water Science Technology*, 51: 187–94.
- Groenewald, Y., 2012. Coal's hidden water cost to South Africa. Greenpeace Africa. South Africa.
- Higgins, S. F., Agouridis, C. T. and Gumbert, A. A., 2008. Drinking water quality guidelines for cattle. UK Cooperative Extension Service, University of Kentucky College of Agriculture. United Kingdom.
- Jarvie, H. P., Neal, C. and Withers, P. J. A., 2006. Sewage-effluent phosphorus: a greater risk or river eutrophication than agricultural phosphorus? *Science of Total Environment*, 306: 243–53.
- Karpiscak, M.M., Foster, K. E. and Schmidt, N., 1990. Residential water conservation. *Water Research*, 26: 939–948.
- Li, F., Wichmann, K. and Otterpohl, R., 2009. Review of the technological approaches for grey water treatment and reuses. *Science of the Total Environment*, 407: 3439-3449.

- Magee, E., 2005. The benefits of yogurt: What's tasty, easy, and has lots of health benefits? Yogurt! WebMD, LLC. Available at: <http://www.webmd.com/diet/features/benefits-of-yogurt>. Date accessed.[2014/07/10]
- March, J. G., Gual, M. and Orozco, F., 2004. Experiences on grey water re-use for toilet flushing in a hotel (Mallorca Island, Spain). *Desalination*, 164: 241.
- Meek, A. J., 1996. Water quality concerns for swine. *Small Farm Today*. 13:15.
- Momba, M.N.B., Tyafa, Z. and Makala, N., 2004. Rural water treatment plants fail to provide potable water to their consumers: the Alice water treatment plant in the Eastern Cape Province of South Africa. *South African Journal of Science*, 100: 307-310.
- Murphy, K. O. 'H., 2006. A scoping study to evaluate the fitness-for-use of grey water in urban and peri-urban agriculture. WRC Report No. 1479/1/06. Water Research Commission, Pretoria, South Africa, 143.
- National Research Council (NRC), 1998. *Nutrient Requirements of Swine* (10th ed.). National Academy Press, Washington, DC, United States of America.
- Nolde, E., 1999. Greywater reuse systems for toilet flushing in multi-storey buildings — over ten years' experience in Berlin. *Urban Water*, 1: 275–84.
- Nyachoti, C. M. and Kiarie, E., 2010. Water in swine production: a review of its significance and conservation strategies. *Manitoba Swine Seminar*, 24: 217-232.
- Nyachoti, C. M., Patience, J. F. and Seddon, I. R., 2005. Effect of water source (ground versus surface) and treatment on nursery pig performance. *Canadian Journal of Animal Science*, 85: 405-407.

- Nyenje, P. M., Foppen, J. W., Uhlenbrook, S., Kulabako, R. and Muwanga, A., 2010. Eutrophication and nutrient release in urban areas of sub-Saharan Africa — A review. *Science of the Total Environment*, 408: 447-455.
- Oberholster, P. J., Botha, A. M. and Cloete, T. E., 2008. Biological and chemical evaluation of sewage water pollution in the Rietvlei Nature Reserve wetland area. South Africa. *Environmental Pollution*, 156: 184-192.
- Oberholster, P.J., Botha, A-M. and Ashton, P.J., 2009a. The influence of a toxic cyanobacterial bloom and water hydrology on algal populations and macroinvertebrate abundance in the upper littoral zone of Lake Krugersdrift, South Africa. *Ecotoxicology*, 18: 34 - 46.
- Okun, D.A., 1997. Distributing reclaimed water through dual systems. *American Water Works Association Journal*, 89: 153–160.
- Pidou, M., 2006. Hybrid membrane processes for water reuse. PhD thesis. Cranfield University, United Kingdom.
- Pidou, M., Avery, L., Stephenson, T., Jeffrey, P., Parsons, S. A., Liu, S., Memon, F. A. and Bruce Jefferson, B., 2008. Chemical solutions for greywater recycling. *Chemosphere*, 71: 147–155.
- Pinder, R. W., Davidson, E. A., Goodale, C. L., Greaver, T. L., Herrick, J. D. and Liu, L., 2012. Climate change impacts of US reactive nitrogen. *Proceedings of the National Academy of Sciences*, 109: 7671–7675.
- Rausch, K. D. and Powell, G. M., 1997. Dairy processing methods to reduce water use and liquid waste load. Kansas State University, Manhattan, United States of America.
- Ravishankara, A. R., Daniel, J. S. and Portmann, R. W., 2009. Nitrous oxide (N₂O): The dominant ozone-depleting substance emitted in the 21st century. *Science*, 123–125.

- Rodda, N., Carden, K., Armitage, N. and du Plessis, H. M., 2011. Development of guidance for sustainable irrigation use of grey water in gardens and small-scale agriculture in South Africa. *Water SA*, 37: 727-738.
- Ross, S. M., Loening, W. E. K. and van Middelkoop, A., 1983a. Breast-feeding evaluation of a health education program. *South African Medical Journal*. 64.
- Ross, S. M., van Middelkoop, A. and Khoza, N. C., 1983b. Breast-feeding practices in a Black community. *South African Medical Journal*, 63.
- Saving Water SA, 2011. Water theft contributes to SA's increasing crisis. Available at: <http://www.savingwater.co.za/tag/water-theft/>. [2015/06/10]
- Statistics South Africa (STATSSA), 2013a. Mid-year population estimates 2013. Available at: <http://www.statssa.gov.za/publications/P0302/P03022013.pdf>. Date Accessed.[2013/07/10]
- Statistics South Africa (STATSSA), 2013b. Quarterly Labour Force Survey Quarter 4, 2013. Available at: <http://www.statssa.gov.za/publications/P0211/P02114thQuarter2013.pdf>. Date Accessed.[2015/06/10]
- Strauss, K. J., 2006. Application of Pinch Technology in water resource management to reduce water use and wastewater generation for an area. Water Research Commission Report No. 1241/1/06. Pretoria, South Africa.
- Strydom, J. P., Britz, T. J. and Mostert, J. F., 1997. Two- phase anaerobic digestion of three different dairy effluents using a hybrid bioreactor. *Water SA*, 23: 151- 156.
- Thorpe, B., 2009. Clean production strategies: What is clean production? Green peace International. United Kingdom.
- van Ginkel, C.E., 2004. A national survey of the incidence of cyanobacterial blooms and toxin production in major impoundments. Internal Report No. N/0000/00/DEQ/0503. Resource Quality Services, Department of Water Affairs. Pretoria, South Africa.

- van Heugten, E., 2000. Guidelines for water quality in pigs. Animal Science Facts: Extension Swine Husbandry. ANS, 00-811S.
- van Rensburg, L. D., Strydom, M. G., Du Preez, C. C., Bennie, A. T. P., Le Roux, P. A. L. and Pretorius, J. P., 2008. Prediction of salt balances in irrigated soils along the lower Vaal River, South Africa. Water SA, 34: 11-17.
- Virto, R., Manas, P., A´lvarez, I., Condon, S. and Raso, J., 2005. Membrane damage and microbial inactivation by chlorine in the absence and presence of a chlorine-demanding substrate. Applied Environmental Microbiology, 71: 5022–5028.
- Veenhuizen, M. F., Shurson, G. C. and Kohler, E. M., 1992. Effect of concentration and source of sulfate on nursery pig performance and health. Journal of American Veterinary Medical Association. 201: 1203-8.
- Walker, J. T., Aneja, V. P. and Dickey, D. A., 2000. Atmospheric transport and wet deposition of ammonium in North Carolina. Atmospheric Environment, 34: 3407–3418.
- Water Research Commission (WRC), 1989. Water and waste-water management in the dairy industry. WRC Project no 145 TT 38/89. NATSURV series no, 4. Published by the WRC, Pretoria, South Africa.
- Winward, G. P., Avery, L. M., Stephenson, T. and Jefferson, B., 2008. Chlorine disinfection of grey water for reuse: Effect of organics and particles. Water Research, 42: 483-491.

Chapter 3: Water conservation and effluent generation in dairy processing plants

Abstract

The objective of the current study was to assess the level of awareness of dairy industries in water conservation and management of effluents. A questionnaire was administered to 233 companies and 103 enterprises responded. Aspects covered includes water usage; types of dairy product, effluent generation and water conservation practices. The influence of period of operation, size and location of company was also assessed. A Proc-Freq procedure and chi-square test of SAS program was used to analyse the data. Water use on different processes was influenced by the size of the company ($P < 0.05$). There was an association ($P < 0.05$) between period of operation and water conservation strategy adopted by companies (80%). Water source was not associated ($P > 0.05$) with size of the company, location and period of operation. The influence of size of company, location and period of operation did not have an impact ($P > 0.05$) on dairy effluent treatment method used. The high proportion of dairy companies adopting irrigation as a major water conservation strategy indicates that alternative sustainable methods of recycling waste water should be developed.

Key words: location, period, size of company

3.1 Introduction

There are global fresh water shortages. In South Africa, for example, the annual fresh water availability is less than 1 700 m³ per capita (Otieno and Ochieng, 2004). It is estimated that by 2025, the country will have fresh water availability of less than 1000 m³ per capita (International Water Management Institute (IWMI), 1996). This scenario is also provoked by inadequate water conservation and recycling occurring in the dairy manufacturing industry. The largest portion of

water within agriculture goes to the dairy industry, of which between 75 and 95 % of the water intake is discharged as effluent (Water Research Commission (WRC), 1989; Department of Water Affairs (DWAF), 2012).

The South African dairy industry has more than 250 dairy processing companies which produce about $1.86 \times 10^9 \ell$ of milk (Strydom *et al.*, 1993). Water use and the effluent discharged vary with the type of product (WRC, 1989; Otieno and Ochieng, 2004). It is highly likely that development of new products processed differently including cheese products and fruit blends being introduced on the market increase water usage, energy and effluent generation (Bijl *et al.*, 2007). Water in dairy processing plants is used for cleaning-in-place and food processing. Cleaning-in-place, which involves all cleaning activity, is the most water consuming activity (WRC, 1989). Substantial amounts of water are also used in the washing of milk truck tanks, vehicle, bottles and crates. Water is used at receiving, pasteurization, filling room, packaging and storage. All these activities generate large volumes of effluent.

The increase in the scarcity of fresh water puts pressure on the dairy industry to develop appropriate ways of conserving water and disposal of the effluent (Strydom *et al.*, 1993). Changes in type of products, in addition to willingness of the management, are likely to influence the extent to which fresh water is conserved and recycling of effluent. Such information enables practitioners in the water industry to develop accurate models on water utilization and for the government to regulate and control water resources. The impact of the strategies adopted on the environment and cost of energy will also be modelled. Therefore, the objective of this study was to assess the level of awareness of dairy industries in water conservation. It was hypothesised that water usage across different sizes of companies is the same, and dairy processing plants do not conserve water.

3.2 Materials and Methods

3.2.1 Sampling of dairy enterprises

A list of South African dairy industries was obtained from the Department of Economic Development and from Milk South Africa, a board of milk producers and processors. The location of companies was divided into two regions namely: coastal region (KwaZulu-Natal, Eastern Cape, Western Cape and Northern Cape) and inland region (Mpumalanga, Free State, Gauteng, North West Province and Limpopo). Companies were categorized into three sizes. Companies processing less than 400 kilolitre (kl) of milk per day, using less than 400 kl of water per month were considered small. Medium scale companies processed between 400 to 900 kl of milk per day. Lastly, large scale companies processed more than 900 kl of milk per day. The survey procedure was approved by Humanities and Social Science Research Ethics Committee (Reference: HSS/0240/014M) of the University of KwaZulu-Natal (Appendix 1).

3.2.2 Questionnaire administration

Questionnaires were developed and covered the following aspects: volume of milk processed; water usage; types of dairy product; water source used, effluent generation and treatment methods and water conservation practices adopted, period, size and location of company. Structured questionnaires were sent to 233 registered milk processors (Appendix 2) via emails and fax. Respondents (production managers) were given four weeks to return the completed questionnaires. Direct phone calls were also made to encourage the companies to complete the questionnaires. Out of 233 questionnaires sent to participants, only 103 questionnaires were returned back answered.

3.2.3 Statistical analyses

All data were analysed using SAS (2008). Associations and proportions (%) of the size of the company, period of operation, type of dairy product, level of water use, water treatment methods used willingness of companies to conserve water, water sources used and water conservation strategies adopted were analysed using chi-square tests and Proc-Freq procedure (SAS, 2008).

3.3 Results

3.3.1 Distribution of South African dairy processing plants

The distribution of the dairy companies that participated in the study is shown in Figure 3.1. Respondents were mostly from the Western Cape (38.5 %), Gauteng (25.2 %), KwaZulu-Natal (16.1 %) and Eastern Cape (10.1 %). Small companies were the most dominant companies across all provinces. Medium-sized companies were mostly found in Western Cape (37.5 %) followed by Gauteng (27.5 %) and KwaZulu-Natal (12.9 %). Large companies were mostly found in Western Cape and Gauteng (37.5 %) and KwaZulu-Natal (18.8 %). Most large (81.3 %) and medium-sized companies (42.5 %) had been in operation for more than 20 years while small companies (42.6 %) have operated for a period of 10 – 20 years.

3.3.2 Major products in South African dairy processing plants

Major dairy products from processing plants are shown in Table 3.1. Pasteurized milk was the leading product; followed by cheese, yoghurt, sour milk, fruit juice blends, fruit juice and ice cream across the scales of companies. More than half of the medium-sized companies (56.8 %) produced pasteurized milk. Cheese was mostly produced by small-sized companies (54.4 %). Cultured

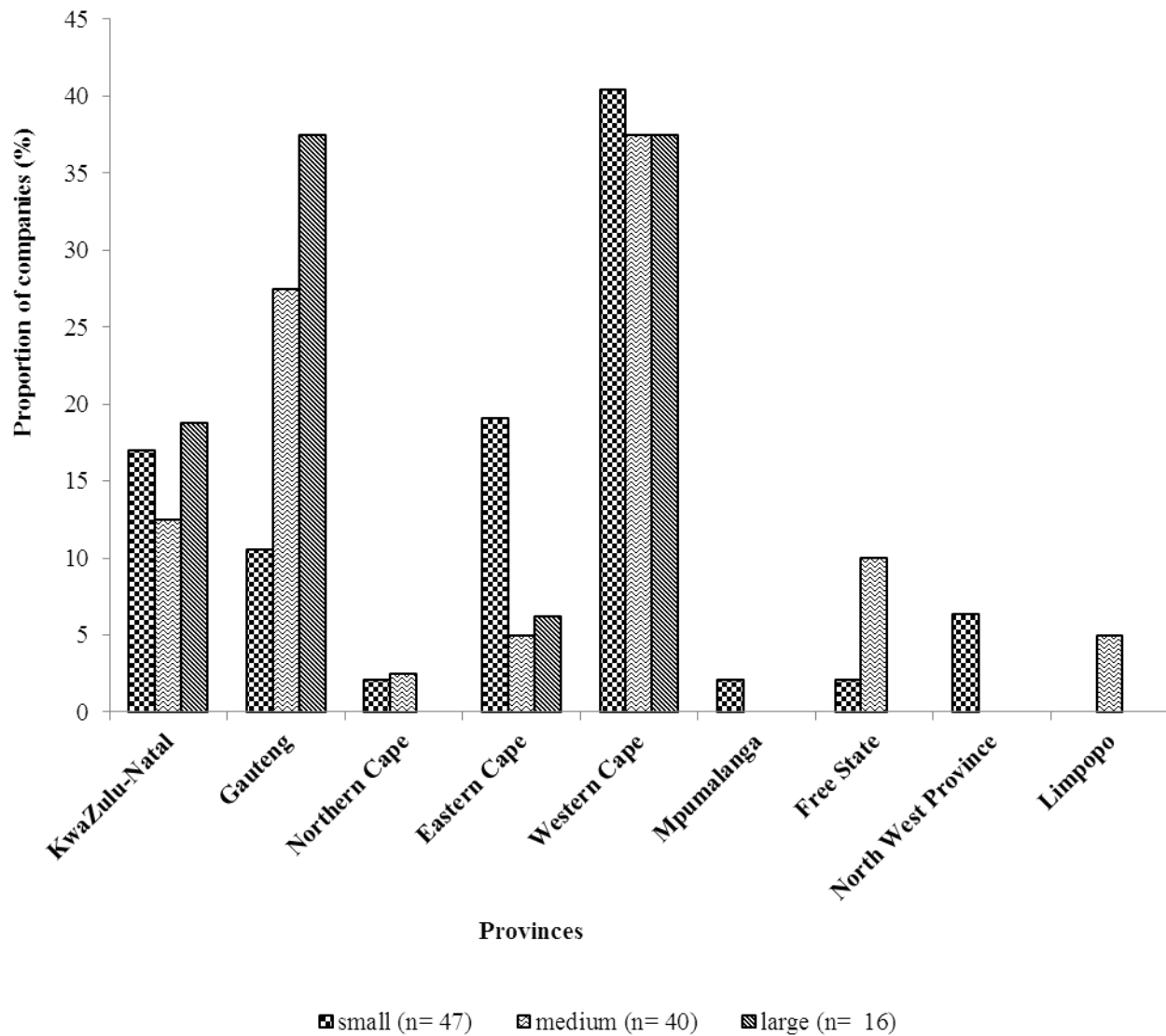


Figure 3.1: Percentage of small, medium and large dairy processing plants that participated in the study

Table 3.1: Major dairy products in dairy processing plants from different size of companies

Product	Proportion of companies (%)		
	Small (n=47)	Medium (n=40)	Large (n=16)
Pasteurized milk	45.7	70.3	61.1
UHT milk	6.5	2.7	11.1
Sterilized milk	2.2	0	11.1
Milk powder	0	5.41	11.1
Processed cheese	8.7	0	0
Cultured butter milk	0	8.1	11.1
Butter	4.4	10.8	11.1
Custard	0	0	11.1
Cheese	54.4	35.1	38.9
Yoghurt	26	37.8	50
Desserts	2.2	0	5.6
Sour milk	8.7	24.3	44.4
Low fat milk	2.2	13.5	5.6
High fat milk	2.2	2.7	11.1
Fruit juice blends	4.4	32.4	33.3
Sour cream	2.2	8.1	22.2
Fruit juice	2.2	24.3	16.7
Ice cream	60.87	27	38.9

products (yoghurt and sour milk) were largely produced by large companies. Fruit juice blends were mostly produced by medium and large companies (65.7 and 33.3 %) followed by medium companies (32.4 %). Ice cream seemed to be popular and produced highly by small companies (60.9 %) compared to large companies (38.9 %).

3.3.3 Water sources used

Figure 3.2 shows the water source used by the companies. Municipal water was the most used source by companies. The second most used source was borehole/ground water. Spring, rain and river water was used less. The least used source was recycled water. There was no association ($\chi^2 = 12.5$; $P > 0.05$) between water source used and the size of the company. No association was also observed between water source and period of operation ($\chi^2 = 10.11$; $P > 0.05$).

3.3.4 Level of water use during processing

As shown in Table 3.2, the proportion of high water use during processing was influenced by the size of the company ($P < 0.05$) in receiving, steaming and cooling stage. As expected, large companies were the highest users of water across different stages of production. High volumes of water were used in receiving, steaming and cooling. Water use during packing, cleaning-in-place and boiling was the same across all sizes of the companies ($P > 0.05$). The association between water use in processing and location was not significant ($P > 0.05$). Similarly, the period of operation and water use in processing had no association ($P > 0.05$).

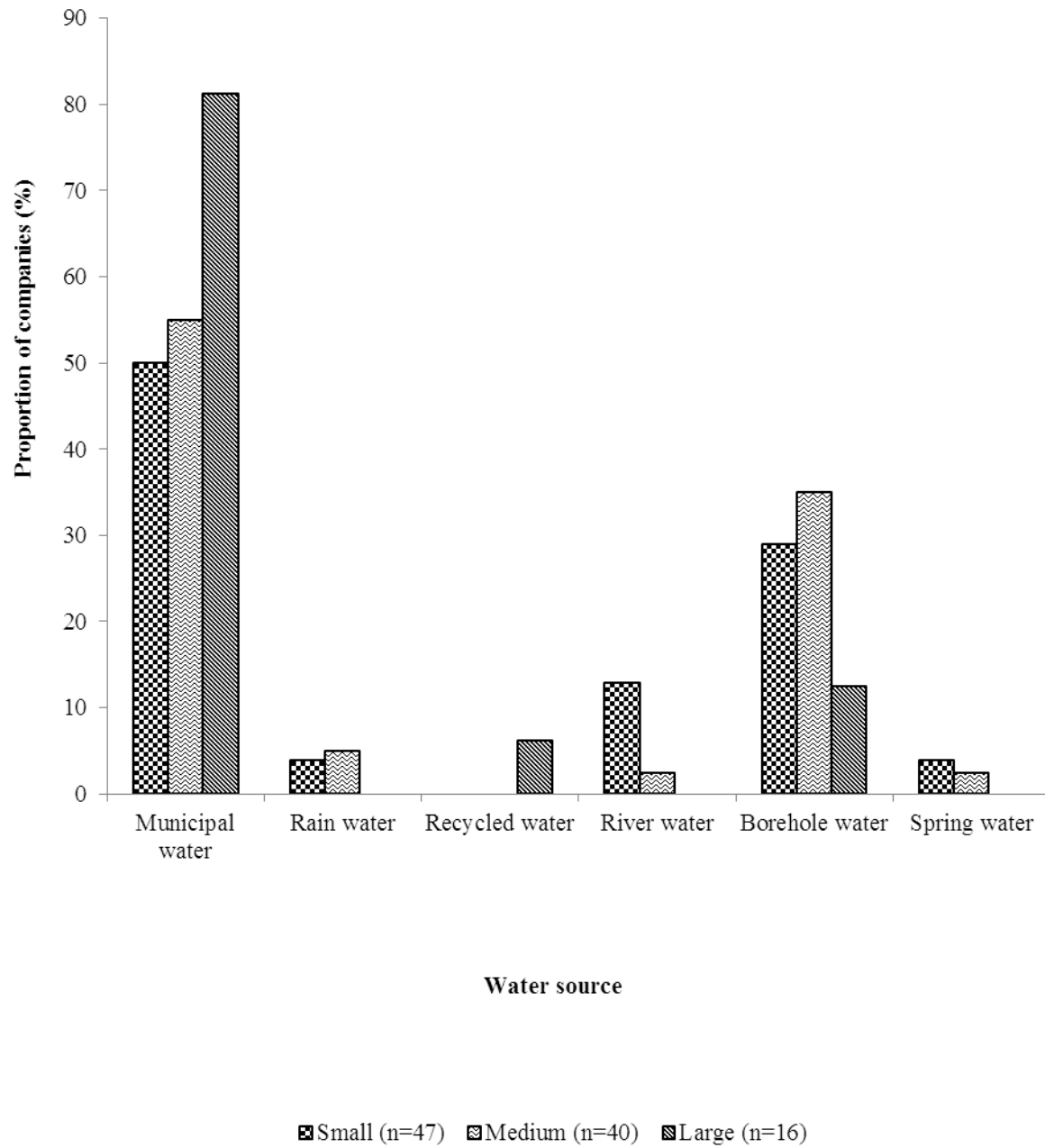


Figure 3.2 Major water sources used by companies

Table 3.2: Proportion of companies with high water use during processing from different size of companies

Processing	Proportion of companies			Significance
	Small (n=47)	Medium (n=40)	Large (n=16)	
Receiving	19.6	12.2	68.8	*
Steaming	17.4	24.4	62.5	*
Filling	13.0	4.9	31.3	*
Cooling	39.1	7.3	93.8	*
Cleaning-in-place	78.3	53.7	93.8	NS
Boiling	54.4	95.1	75.0	NS

*P<0.05, NS – not significant (P>0.05).

3.3.5 Water conservation strategies

Majority of companies (80 %) are conserving water. High proportion of companies (17%) used irrigation strategy between a period of 10 to 20 years, while 8.7% of companies used irrigation for more than 20 years and 6.8% of companies used the strategy for less than 10 years (Table 3.3). Recycling on the other hand has been used by 10% of companies for less than 10 years while 7.8% of companies used the strategy between periods of 10 to 20 years and 4.9% of companies used the strategy for more than 20 years. Cleaner production which is a strategy that minimizes waste and emissions and maximizes product output; and Livestock drinking which is dairy effluent used for drinking by animals, were the least used strategies by companies over period (Table 3.3). Period of operation was observed to be associated ($\chi^2 = 93.5$; $P < 0.05$) with water conservation strategy. There was no association observed on size ($\chi^2 = 16.8$; $P > 0.05$) and water conservation strategy. Similarly the association between location and water conservation strategy was not significant ($\chi^2 = 7.8$; $P > 0.05$).

3.3.6 Generation and treatment methods of dairy effluent

As expected, the dairy effluent volumes generated were influenced by the size of the company. Small companies, utilizing about 500 kl of water per month, generated over 400 kl of effluent. Medium and large companies also produced, on average, 8 500 and 30 000 kl of dairy effluent per month, respectively. The bulk of the companies channelled these dairy effluents to the municipality sewer systems. About 5 % of the companies channelled the effluent into nearby river systems.

Water treatment methods (physical, chemical and biological) are shown in Figure 3.3. There were 61 % companies that did not treat water before disposal. Chemical treatment which is a method

Table 3.3: Association of period of operation with water conservation strategies adopted by companies

Conservation strategy	Proportion of period for Companies (%)			Significance
	<10 years	10 - 20 years	>20 years	
Cleaner production	1.9	1	1	NS
Livestock drinking	0	1.9	1	NS
Water pinch	1.9	4.9	0	NS
Irrigation	6.8	17	8.7	*
Recycling	10.7	7.8	4.9	*

*P<0.05, NS – not significant (P>0.05).

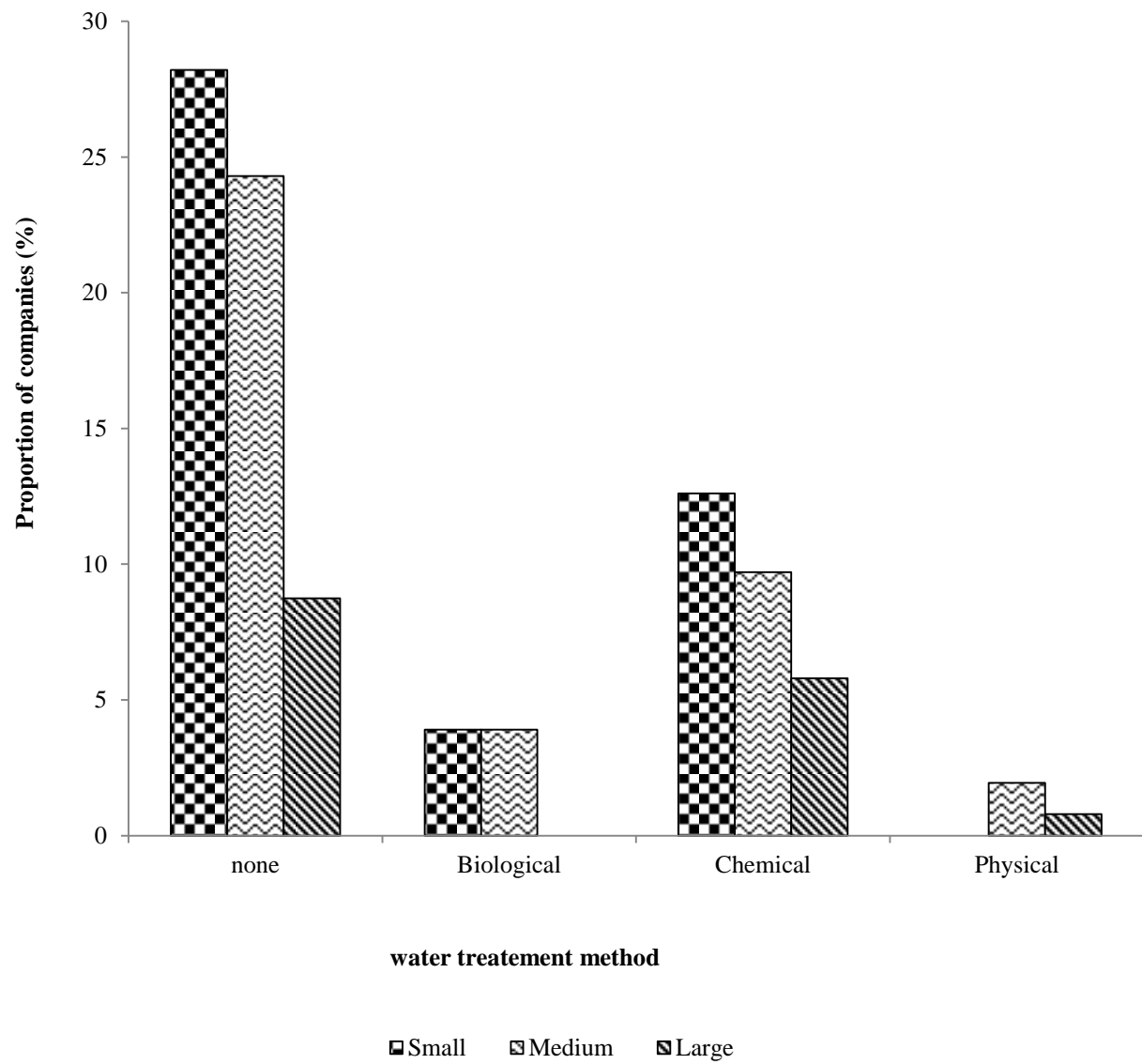


Figure 3.3: Waste water treatment method used by different companies

used to purify water by means of chemicals mostly chlorine was the most used method to treat water. Biological treatment which involves naturally occurring bacteria at higher concentrations in tanks which remove small organic carbon molecules by ‘eating’ them thereby cleaning wastewater; and Physical treatment which is a method that purifies water by means of gravity in separated ponds, were the least treatment methods used by companies. The association between water treatment method and size of the company was not significant ($P>0.05$). The location as well was observed to have no association ($P>0.05$) with water treatment method. Period of operation of the company also indicated to have no association ($P>0.05$) with water treatment method.

3.4 Discussion

The abundance of dairy processing plants situated in Western Cape, Gauteng, KwaZulu-Natal and Eastern Cape could be due to water availability, suitability of environmental conditions and availability of milk from producers. A large number of small to medium scale companies, operating for more than 20 years indicates that majority of the countries milk processed is less than 900 kl of milk per day. The majority of firms used between 400 and 2000 kl of water per month. Strydom *et al.* (1997) reported an average of 1522 kl.d⁻¹ (45 660 kl per month) water use and average milk reception of 159 kl.d⁻¹. This reflect that water use within dairy industry is decreasing thus companies are getting more responsible in saving water. The understanding of nutrients availability such as vitamin A which is essential for eye adjustment (Bellows & Moore 2014) and the need for milk with cereal increases a pressure for demand resulting in an increased production of pasteurized milk. Department of Agriculture Forestry and Fisheries (DAFF) (2012) reported an increase in production of pasteurized milk by 52 %. This figure is still expected to increase due to increase in demand of milk, which is likely due to teenage pregnancies and professional women who are

increasingly using formula feeding; school feeding schemes to minimize malnutrition, and prevention of mother-to-child diseases (Ross *et al.*, 1983a; Ijumba *et al.*, 2014). Therefore, water consumption is still expected to increase dramatically since water intake to volume of raw milk ratio is 0.01 – 9.5, while water used per 1kl of milk produced takes about 3 kl (Strydom *et al.*, 1993; 1997). The size of company will also play a huge role towards water use as it is expected to increase but varying with the company size.

A high percentage of cheese is linked to affordability and nutrient availability of the product resulting in increased demand, hence, cheese market is showing an increase on sales (Cheese Market, 2014). One kilogram of cheese takes about 10l of milk (Madmillie, 2011). Cheese factory use about 2.95 kl.d⁻¹ of water per 1 kl.d⁻¹ of milk processed (Strydom *et al.*, 1997). This indicates that as the demand for cheese increases more milk will be required. The understanding of nutrients and beneficial bacteria (probiotics) contained in cultured products (yoghurt and sour milk) though beneficial to human health also add an increase in production for the two products (Magee, 2005). The high perception of yoghurt comparing to sour milk could be due to vitamin B-2, B-12, potassium, magnesium and calcium that this product has, hence it helps to prevent osteoporosis (Magee, 2005). The increases in production of fruit juice, fruit juice blends and ice cream is highly influenced by high temperatures experienced in recent days. Many people use these products to quench their thirst during warm seasons. Therefore, the increase in demand for dairy products will influence the increase of water demanded which will also influence effluent generation but varying in different sizes of the company.

A high use of municipal water by companies could be linked with water availability and limitation of companies to extract water from rivers. Majority of surface water resources in the country, which are the main sources of water supply, are headed by municipalities (DWAF, 2011). The cheap price of water compare to electricity and ability of municipalities to treat and recycle water also makes companies to buy water. The lack of companies to extract water from springs and harvest rain water due to shortage of resources and finance enforce them to depend much on municipalities. As a result municipalities becomes the main supplier for most companies. The ability of companies to use river water could be due to potential of land catchment. Most coastal provinces (KwaZulu-Natal, Eastern Cape, Western Cape) and some inland provinces (Mpumalanga and Limpopo) in the country have potential catchments of water; therefore river, spring and rain water becomes a supplementary source if not the main source for them.

The observation that water source was not influenced by size of the company could be linked with source of water used. Most (61.7 %) companies use municipal water. Due to price and services that municipality provides, and lack of companies to have adequate resource in order to acquire for other water sources, municipal water becomes favoured. The lack of association for location and water source was not expected. Water sources like borehole were expected to be influenced by location. For companies located in dry provinces or semi-arid areas including Free State, Northern Cape, North West Province, part of Eastern Cape and Western Cape borehole water becomes the main resource due to dryness of the land and shortage of rain water (Council for Science & Industrial Research (CSIR), 2010). Esterhuizen *et al.* (2012) reported that semi-arid areas particularly in South Africa including Free Sate are receiving less rain fall therefore; borehole water becomes the main source of water for companies including farms. Department of Water Affairs (DWAF) (2011) also reported that groundwater is extensively utilized in rural and arid areas.

Therefore, companies located in Free State, Northern Cape, North West Province, part of Eastern Cape and Western Cape were expected to use borehole water since they are in dry areas.

The effect of temperature in drying out rivers and reducing rainfall occurrence gives an indication that borehole water use is likely to increase over years since municipalities are facing the pressure to handle competition between companies and humans for water consumption. Use of borehole water reduce water costs. The disadvantage however of it is the ability of borehole to dry up easily and have reduced water quality. This is caused by contamination of organic material, bacteria and virus (Bedient *et al.*, 1984; Esterhuizen *et al.*, 2012).

The lack of association for period and water source could be due to water shortage or in consistence of water supply from the source. The effect of environmental conditions in reducing water availability in rivers, dams or lakes is likely to cause a change in companies for water source over period. The reduction of water quality due to organic contamination, bacteria and virus for ground water would also make the company to change the water source to the next better available one (Bedient *et al.*, 1984). The reduced water supply from municipality also makes companies to use the next available source. Therefore, due to these factors, period of operation on water source would be highly affected, making companies to not rely on one source over long period of operation.

The high perception of companies to use high volume of water in large companies compare to small and medium scale companies during receiving and steaming could be linked with the type of a product produced. Water use during production of different product differs. Water used to produce 1kg of cheese is 2.94 ℓ while in production of 1 ℓ of fresh milk, 3.06 ℓ of water is used (Strydom *et al.*, 1997). Due to volume of products processed in different companies, large companies yield high

volume of water since they produce variety of products in huge amounts. The perception of large companies to use high volumes of water in cooling while small and medium companies use less water is highly linked with the machinery used during processing. The pasteurizer machine used in large companies is an automatic closed system or high temperature-short time (HTST) pasteurizer while small and medium companies use an open system pasteurizer (Newhouse, 2010; Appendix 3). An open system pasteurizer is highly favoured by the effect of temperature since the system is open while the closed system is not, therefore, water use in closed system will be in order to cool the milk as compared to an open system which is assisted by the environment to cool the milk.

The association of high water use during various processes on different companies was expected. Food Agriculture Organization (FAO) (1996) report has also confirmed that size of the company and different processes of different products influence water use. Ikhu-Omoregbe and Masiwa (2002) reported a water use of 1084 kℓ. y⁻¹ and 36 150 kℓ. y⁻¹ for small and large companies which reflect the effect of size. Strydom *et al.* (1997) reported a water usage of 495 kℓ. d⁻¹ for cheese factory, 682 kℓ. d⁻¹ for fresh milk and 390 kℓ.d⁻¹ for milk powder, which reflect the effect of products on water use. Carawan *et al.* (1979a) reported a water usage of 30 % from utilities and 38 % from cleaning and sanitizing, which reflect the influence of processing on water usage in conjunction with size of the company. Therefore, the association of high water use with different processes on different companies observed current findings reveal that water use is influenced by size of the company.

The lack of association on processes which include cleaning-in-place and boiling, and size of the company could be linked with management practiced. The practice of these processes is common across size-scale of companies hence water use is high especially on cleaning-in-place. Carawan *et*

al. (1979a) also reported a high volume of water up to 38 % during cleaning-in-place. Water Research Commission (WRC) (1989) reported a water intake of 60 % used for cleaning-in-place. Cleaning-in-place is divided into three stages (WRC, 1989). The first stage is a hot or pre rinse washing performed to get rid of loosely held substances. The second stage is the hot caustic wash used to wash the equipment. The third stage is the cold final rinse which removes small substances of caustic. Therefore, this reflects that water use during these processes is high across all sizes.

Having a lack of association on water use and period was not expected. The introduction of new products comes with new different processes or technologies (FAO, 1996). Water use, however is influenced by product. Therefore, as the time goes, water usage differs due to product and processes used. For example, the old used pasteurizer system was an open system which would boil the milk and allowing it to cool for some time before the milk get released for further processing. The new closed system pasteurizer (HTST) has hot pipes that boils the milk at 75°C for 15 seconds then quickly cool it at cooling pipes at 4.4°C (WRC, 1989; Newhouse, 2010; Appendix 3).

The majority of companies (61.2 %) that do not treat water before disposal indicate that they depend on the local municipalities for water. Municipalities have waste water management structures that recycle waste. Companies are subjected to reach certain maximum levels of pollutant loads in order to be charged free. Once they exceed those levels they get charged by the municipality for polluting water (Sai, 2014). An example is a COD level for waste water which must be less than 9,000 kg. d⁻¹ for a wide range of temperatures which can range from 14 to 19°C (Mikosz, 2015). If the company exceeds this level, it can be charged thousands of rand depending with the municipality tariff. Carawan *et al.* (1979b) reported that effluent volume with biochemical

oxygen demand (BOD) above 300 mg/litter and of total suspended solids (TSS) above 300 mg/litter could be charged \$.16336/kg (R198 858.13).

The most common treatment method is chemical treatment which consists of using chlorine (Winward *et al.*, 2008). Companies use caustic soda and acid, thus it is cost effective, widely available, does not require much equipment or technology and easy to apply (The City of Muskogee, 2006). Chlorine disinfection, however, can form trihalomethanes (THMs) if it included in higher concentration than the maximum contaminant standard which may lead to cancer (The City of Muskogee, 2006). The lack of association of treatment method and size of the company was not expected. The expected results were that large companies would be major users of chemical treatment. Large companies have their own treatment station hence they produce high effluents with high pollutant loads (WRC, 1989). Small to medium companies don't have treatment stations due to lack of finance hence they produce low effluents compare to large companies; therefore, they would rely on municipalities (Ikhu-Omoregbe and Masiwa, 2002).

Dairy companies that have crops or pasture are known to use dairy effluent in supplementing water to their crops (WRC, 1989; Strydom *et al.*, 1993). Before water gets applied to crops, it is firstly treated with physical method. Waste water from the company is taken to filter beds. From there, waste gets felted to the ground. The water from the top is pumped by the pumping machine to irrigate the pasture. Companies that are located in KwaZulu-Natal, Limpopo, Mpumalanga, Gauteng, parts of Western Cape and Eastern Cape, are situated in areas with fertile soils and adequate rainfall are that support the crop growth. These companies use dairy effluent for irrigation. Therefore, influence of location to treatment method (physical method) was then expected to be significant.

The observation that nearly 85 % of the companies that saves water indicates that companies are becoming increasingly responsible of water usage hence precaution are taken during processing. The continuous implementation of water conservation strategies and increasing level of awareness would result in reduction of effluents released by companies. The association between period of operation and conservation strategy indicates the progress of companies on operation of implementing the strategies. Irrigation has been observed as the most used method. Irrigation saves fresh water use for irrigation. This method has been used for decades hence the current study also reveals that. Due to its potential in recycling organic matter and other soil nutrients which then reduce fertilizer cost and the use of synthetic fertilizer (Jiménez, 2006); irrigation becomes more popular. The volumes of effluent that are generated by dairy companies are so large that sustainable ways of recycling the effluent needs to be devised. Recycling of these effluents, particularly those from washing and cleaning equipment would greatly reduce the demand for fresh water and also reduces water costs. Opportunities for recycling, however, depend on the pollutant loads of the effluent.

The significance of water recycling and period indicates the improvement on water conservation in the industry. The use of this strategy for less than 10 years by majority of companies can be linked with equipment used for processing. The recently used pasteurizer system (closed automatic pasteurizer system) has capability of recycling water from the cooling machine and boiling machine (Newhouse, 2010; Appendix 3). This is done at this part because this is where water is mostly used in dairy processing plants. Therefore, controlling water at this point would result in huge saving of water costs; water use and effluent generation.

The lack of association of water conservation strategy with size of company is highly influenced by management of the company (WRC, 1989). Regardless of the size of the company, the willingness of management to save water or increase awareness of water conservation is the one that would influence the adoption of water conservation strategy. The lack of influence from location and water conservation strategy was not expected. Companies located in provinces that lack water intake from rain, rivers or lakes are one expected to be precaution with saving water since water availability is low on those provinces. Esterhuizen *et al.* (2012) mentioned that companies located in such provinces uses borehole water as a water source. Strydom *et al.* (1993) revealed that discharging effluents into land or pasture by irrigation becomes the common practice by companies. Therefore, water use and conservation is expected to be the priority in companies found on such location.

Other conservation strategies (cleaner production, livestock drinking and water pinch) give an indication that more work is still required to implement them. Although these strategies has been used before especially water pinch by minority over the last 15 years, the majority was not aware hence they are still adapting to the strategy (Strauss, 2006). Livestock drinking water source is still expected to be practised over years. Effluents from cheese making has potential to be used due to whey content contained by the effluents. This will have positive effect on growth performance of broilers if water could be balanced adequately with feed (Shariatmadari and Forbes 2005).

3.5 Conclusions

Water use was not influenced by location of company or period of operation, but, affected by size of company. Large companies utilised high volumes of water compare to medium or small company. Water conservation strategy was not associated with size or location of company,

however, it was influenced by period of operation. The ability of companies to adopt irrigation as a major water conservation strategy for a period of 10 to 20 years signifies the willingness of companies to save water. The hypothesis that water usage across different sizes of companies is the same, and dairy processing plants do not conserve water is rejected. Alternative sustainable methods of recycling waste water should be developed. This could start with assessing pollutant loads in the dairy effluent generated. The loads will be useful in making decisions about how the effluent can be re-cycled or re-used.

3.6 References

- Bedient, P. B., Rodgers, A. C., Bouvette, T. C., Tomson, M. B. and Wang, T. H., 1984. Ground-Water Quality at a creostote Waste Site. *Groundwater*, 22: 318-329.
- Bellows, L. and Moore, R., 2014. Fat-soluble vitamins: A, D, E, and K. Colorado State University. United States of America.
- Bijl, R., Kooistra, S. R. and Hogeveen, H., 2007. The profitability of automatic milking on Dutch dairy farms. *Journal of Dairy Science*, 90: 239-248.
- Carawan, R. E., Jones, V. A. and Hansen, A. P., 1979a. Water use in a multiproduct Dairy. *Journal of Dairy Science*, 65: 1238-1242.
- Carawan, R. E., Jones, V. A. and Hansen, A. P., 1979b. Water characterisation in a multiproduct Dairy. *Journal of Dairy Science*, 62: 1243-1251.
- Cheese Market, 2014. Dairy co-market information. Available at:
<http://www.dairyco.org.uk/market-information/dairy-sales-consumption/cheese-market/cheese-market/#.U80pG-OSxMg>. Date accessed. |2014/07/21|

- Council for science and industrial research (CSIR) (2010) A CSIR perspective on water in South Africa – 2010. URL:
http://www.csir.co.za/nre/docs/CSIR%20Perspective%20on%20Water_2010.PDF (Accessed 09 July 2013).
- Department of agriculture, forestry and fisheries (DAFF) (2012) A profile of the South African dairy market value chain. Pretoria. South Africa.
- Department of water affairs (DWA) (2011) Governing board induction manual, Chapter 1: Overview of the South Africa's water sector. Pretoria, South Africa.
- Esterhuizen, L., Fossey, A. and Lues, J. F. R., 2012. Dairy farm borehole water quality in the greater Mangaung region of the Free State Province, South Africa. *Water SA*, 38: 803 - 806.
- Food Agriculture Organization of United Nations (FAO), 1996. Management of waste from animal product processing. Available at:
<http://www.fao.org/WAIRDOCS/LEAD/X6114E/X6114E00.HTM>. Date Accessed |2013/08/09|
- Ijumba, P., Doherty, T., Jackson, D., Tomlison, M., Sanders, D. and Persson, L., 2014. Free formula milk in the prevention of mother-to-child transmission programme: voices of a peri-urban community in South Africa on policy change. Oxford University Press, 24.
- Ikhu-Omoregbe, D. I. O. and Masiwa, H., 2002. A postal survey of effluent generation and disposal in the Zimbabwean dairy industry. *Water SA*, 28: 179 – 182.
- International Water Management Institute (IWMI), 1996. World water demand and supply, 1990 to 2025: scenarios and issues. Research Report Number 19.

- Jiménez, B., 2006. Special feature on groundwater management and policy: Irrigation in developing countries using wastewater. *International Review for Environmental Strategies*, 6: 229 – 250.
- Madmillie, 2011. Cheese: General and questions. Available at:
<http://www.madmillie.com/Help/FAQs/Cheese/General+Questions.html>. Date accessed.
 |2014/07/10|
- Magee, E., 2005. The benefits of yogurt: What's tasty, easy, and has lots of health benefits? Yogurt!WebMD, LLC. Available at: <http://www.webmd.com/diet/features/benefits-of-yogurt>. Date accessed.|2014/07/10|
- Mikosz, J., 2015. Determination of permissible industrial pollution load at a municipal wastewater treatment plant. *International Journal of Environmental Science Technology*, 12: 827–836.
- Newhouse, D., 2010. Pasteurizer operator study Guide: Reference and study guide for the HTST and Vat pasteurizer operator. Washington Department of Agriculture, United States of Agriculture.
- Otieno, F. A. O. and Ochieng, G, M, M., 2004. Water management tools as a means of averting a possible water scarcity in South Africa by the year 2025. *Water SA*, 30: 120.
- Ross, S. M., Loening, W. E. K. and van Middelkoop, A., 1983a. Breast-feeding evaluation of a health education programme. *South African Medical Journal*, 64.
- Sai, S., 2014. Biological treatment of dairy industry waste water and its comparison with other treatment techniques. Academia. Available at:
http://www.academia.edu/5635632/Biological_Treatment_of_Dairy_Industry_Waste_water_and_its_comparison_with_other_Treatment_Techniques. Date accessed.
 |2014/08/03|
- SAS, 2008. SAS Users Guide: Statistics, version 9.1. SAS Institute, Cary, NC, USA.

- Shariatmadari, F. and Forbes, J. M., 2005. Performance of broiler given whey in the food and /or drinking water. *British Poultry Science*, 46: 498-505.
- Strauss, J., 2006. Application of Pinch technology in water resource management to reduce water use and wastewater generation for an area. Water Research Commission. Pretoria, South Africa.
- Strydom, J. P., Britz, T. J. and Mostert, J. F., 1993. Effluent production and disposal in the South African dairy industry: A postal survey. *Water SA*, 19: 253 – 258.
- Strydom, J. P., Britz, T. J. and Mostert, J. F., 1997. Two- phase anaerobic digestion of three different dairy effluents using a hybrid bioreactor. *Water SA*, 23: 151- 156.
- The City of Muskogee, 2006. Water treatment plant: Reasons for using chlorine. Available at: <http://www.cityofmuskogee.com/shell.asp?pg=131>. Date accessed,|2014/08/03|
- Water Research Commission (WRC), 1989. Water and waste-water management in the dairy industry. National Industrial Water and Waste-water Survey 4. Pretoria, RSA.
- Winward, G. P., Avery, L. M., Stephenson, T. and Jefferson, B., 2008. Chlorine disinfection of grey water for reuse: Effect of organics and particles. *Water Research*, 42, 483- 491.

Chapter 4: Effect of size of the company on dairy effluent pollutant loads from South African dairy companies

Abstract

The objective of the study was to investigate the effect of size of company and type of products on dairy effluent produced at dairy processing plants. Processing plants were categorized into small ($n = 10$); medium ($n = 10$) and large scale ($n = 10$) companies. A total of 150 dairy effluents samples were collected. Sources included wash equipment (milk tanks, pasteurizer and vats), product effluents (cheese, milk, yoghurt, fruit juice and sour milk), machine cooling effluent, effluent mixture before treating and effluent mixture after treating. Effluents were collected and analysed for chemical oxygen demand (COD), suspended solids, nitrate/nitrite concentration, chloride, colour, dissolved calcium, dissolved magnesium, fluoride, pH, sulphate concentration, total dissolved solids (TDS), total hardness, turbidity and total coliform. Location did not affect ($P > 0.05$) pollutant loads except for fluoride concentrations ($P < 0.05$). Size of company had high impact ($P < 0.001$) on pollutant loads except ($P > 0.05$) in sulphate concentration. Type of product affected ($P < 0.001$) pollutant loads. Water treatment reduced pollutant loads except for ($P > 0.05$) suspended solids, fluoride concentration and pH. Effluent generated from washing equipment, products and pasteurizer cooling machine were affected by size and type of products but not the location of the dairy company.

Key words: chemical oxygen demand, coliform, dissolved calcium, suspended solids, total dissolved solids, products.

4.1 Introduction

South Africa dairy sector is, however, facing a challenge in managing the re-use of waste water (Water Research Commission (WRC), 1989). This could be due to high pollutant loads associated with the dairy effluents. Different types of products and sizes of company yield different pollutant loads (Food Agriculture Organization (FAO), 1996). The high pollutant loads, effluent volume and disposal methods in managing waste water should be understood to manage the reuse of waste water from dairy processing plants.

Waste water generated from dairy industries includes dairy effluent and black water (water from toilet). Dairy effluent is waste water which is mainly generated from cleaning-in-place and food processing in dairy industry which excludes water from toilet (Carawan *et al.*, 1979a). Large volumes of water are used for washing of tanks, crates and floors (Water Research Commission (WRC), 1989; Chapter 3), thereby generating huge volumes of effluent. In food processing, the most predominant dairy effluent is generated from products including cheese, milk, butter and ice cream. The re-use of dairy effluent depends on its pollutant loads.

Very few, if any, studies did not determine the effect of size of the company on pollutant loads. The lack of data on the effect of size of company yields misleading conclusions that different companies generate similar types of effluents (Ikhu-Omoregbe and Masiwa, 2002). In South Africa, the latest report on water utilisation and wastewater generation in dairy industry was last performed in 1993 (Strydom *et al.*, 1993). Therefore, there is need to update this information so as to produce appropriate solutions in addressing issues of effluent generation and water conservation from dairy industry.

The effect of size of the company on dairy effluent pollutant loads could be linked to the type of products and processes followed. For example, large companies mostly produce hard cheese while small companies produce soft cheese. These cheese types generate different effluent pollutant loads. Also equipment used in large scale companies differs from the one used in small scale dairy industries (FAO, 1996). These differences lead to different volumes and concentrations of pollutant loads. In Chapter 3, it was revealed that dairy companies generate excessively large volumes of effluent. Strategies to recycle the effluent largely depend on understanding their pollutant loads. The objective of the study was therefore, to assess the effect of size of company and type of products on dairy effluent generated from dairy processing plants. It was hypothesised that size of company and type of products does not influence dairy effluent generated from dairy processing plants.

4.2 Materials and Methods

4.2.1 Sample collection and analyses

Thirty dairy processing plants that were willing to participate in the study were randomly selected for sample collection. Processing plants were categorized into three sizes namely: small scale (n=10); medium scale (n=10) and large scale (n=10). Companies processing less than 400 kl of milk per day, using less than 400 kl of water per month and operating at less than 12 900 kWh electricity per month were considered small. Medium scale companies processed between 400 to 900 kl of milk per day, using less than 400 - 2000 kl of water per month and operating at between 12 900 and 25 800 kWh of electricity per month. Lastly, large scale companies processed more than 900 kl of milk per day, using more than 2000 kl per of water per month and operating at more than 12 900

kWh electricity per month. Dairy effluent samples were collected from KwaZulu-Natal, Gauteng, Eastern Cape, Western Cape, Free State and Limpopo Provinces.

A total of 150 dairy effluents samples were collected in sterilized 1ℓ plastic bottle and 150 ml plastic beaker (for coliform) and stored at $5 \pm 1^{\circ}\text{C}$. On each company, five samples were collected. Samples came from dairy effluent which include wash equipment (milk tanks, pasteurizer, and vats), product effluents (cheese, milk, yoghurt, fruit juice and sour milk), effluent mixture before treating, effluent mixture after treating, and machine cooling effluent. Effluents were collected at the end stage of each production line. Samples were analysed at Talbot Laboratories, Pietermaritzburg.

4.2.2 Parameters analysed

Parameters analysed are shown in Table 4.1. Details on the laboratory protocols followed are given in Appendix 4.

4.2.3 Statistical analyses

Statistical analysis of the data was performed with SAS (2008). The effect of the size, product, water treatment and location on pollutant loads was analysed using general linear model (GLM) according to the following model:

$$Y_{ijkl} = \mu + S_i + T_j + W_k + L_l + \epsilon_{ijkl}$$

Table 4.1: Parameters analysed

Parameter	Procedure/Method	Source
Chemical oxygen demand (COD)	Closed Reflux, Titrimetric Method	Burns and Marshall (1965)
Suspended solids	Standard operating procedure	Degen and Nussberger (1956)
Nitrate/nitrite concentrations	Lachat method	Lachat Instruments (1998)
Chloride concentration	Standard operating procedure	Standard Method Committee (1998)
Colour unit	Standard operating procedure	Klyachko (2002)
Dissolved calcium	Calculation method	Standard Method Committee (1998)
Dissolved magnesium	Standard operating procedure	Symons and Morey (1941)
Fluoride concentration	SPADNS Method	Bellack and Schouboe (1968)
pH	Calibration method	Meade (2005)
Sulphate	Turbidimetric method	Rossum and Villarruz (1961)
Total dissolved solids (TDS)	Standard operating procedure	Sokoloff (1933)
Total hardness	EDTA titrimetric method	Standard Method Committee (1998)
Turbidity	Nephelometric method	U.S. Environmental Protecting Agency (1993)
Total coliforms	Standard operating procedure	Bartram and Pedley (1996)

Where:

Y_i : is the dependent variable (COD, suspended solids, nitrate/nitrite, chloride, colour, dissolved calcium, dissolved magnesium, fluoride, pH, TDS, total hardness, turbidity and total coliform).

μ : is the overall mean

S_i : size of company; T_j : type of product; W_k : treatment of water; L_l : location of company

$\epsilon \sim N(0, \sigma^2\epsilon)$ represent the unexplained random error. The Tukey test was used to separate means.

4.3 Results

4.3.1 Summary statistics

Table 4.2 shows the number of observations, mean for pollutant loads, and standard deviation (SD), minimum and maximum values of the dairy effluent. Variables observed to have higher means were total coliform counts, COD, suspended solids, total harness, turbidity and fluoride concentrations.

4.3.2 Washing effluents from different sizes of companies

Table 4.3 shows the effect ($P < 0.05$) of size of company on colour, dissolved calcium, dissolved magnesium, fluoride, pH, TDS, total hardness, chloride and total coliform. The size of the company did not ($P > 0.05$) affect COD, suspended solids, turbidity and nitrate/nitrite and sulphate concentrations. Chloride concentrations was affected ($P < 0.05$) by small companies followed by large companies and least by medium companies. The concentration of colour, dissolved calcium, dissolved magnesium, fluoride concentrations, TDS and total hardness decreased ($P < 0.001$) with the size of dairy company. The pH level was highly affected ($P < 0.001$) by small companies followed by large companies and least by medium companies.

Table 4.2: Summary statistics of analysis for waste water pollutant loads

Variable	N	Mean	SD	Minimum	Maximum
Chemical oxygen demand (mg O ₂ /l)	150	4831.00	10298.00	20.00	102178
Suspended solids at 105°C (mg/l)	150	1564.00	8881.00	10.00	108090
Nitrate/ nitrite concentration (mg/l)	150	4.24	9.80	0.01	43
Chloride concentration (mg/l)	150	221.71	587.45	5.00	6048
Colour (mg Pt-Col/l)	150	52.27	196.61	1.00	2010
Dissolved calcium (mg/l)	150	62.25	86.74	6.90	488
Dissolved magnesium (mg/l)	150	12.56	11.99	1.00	63
Fluoride concentration (µg/l)	150	1605.00	1929.00	80.00	12000
pH at 25°C	150	6.66	2.14	3.43	12.68
Sulphate concentration (mg SO ₄ /l)	150	44.89	69.37	4.48	474
Total dissolved solids at 180°C (mg/l)	150	2135.00	3006.00	59.00	17760
Total hardness (CaCO ₃)	150	199.87	259.66	23.00	1424
Turbidity (NTU)	150	1411.00	2500.00	0.40	21080
Total coliform (cfu/100ml)	150	139018.00	289691.00	1.00	996000

SD: standard deviation.

Table 4.3: Effect of size of the company effluents obtained from washing equipment

Parameter	Size of the company			SE	Significance
	Small	Medium	Large		
Chemical oxygen demand (mg O ₂ /l)	3350	5747.2	1286.6	2084.4	NS
Suspended solids at 105°C (mg/l)	1003.8	10	994	328.4	NS
Nitrate/ nitrite concentration (mg/l)	1.02	1.55	2.3	0.56	NS
Chloride concentration (mg/l)	239.7 ^c	5 ^a	39.2 ^{ab}	54.2	*
Colour (mg Pt-Col/l)	8.3 ^c	4.6 ^b	1 ^a	1.09	***
Dissolved calcium (mg/l)	58 ^c	35 ^b	13 ^a	5.16	***
Dissolved magnesium (mg/l)	16.1 ^c	14 ^b	4.4 ^a	0.67	***
Fluoride concentration (µg/l)	3630 ^c	445 ^{ab}	100 ^a	407.8	***
pH at 25°C	8.4 ^b	5.15 ^a	6.17 ^c	0.62	***
Sulphate concentration (mg SO ₄ /l)	65.5	9.5	13.05	20.5	NS
Total dissolved solids at 180°C (mg/l)	3572.1 ^c	225 ^{ab}	76 ^a	578.1	***
Total hardness (CaCO ₃)	212.1 ^c	70 ^b	51 ^a	15.6	***
Turbidity (NTU)	1100.9	388	162.56	440.1	NS

^{abc} Values in the same row with different superscripts differ ($P < 0.05$).

SE: standard error.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS – not significant ($P > 0.05$).

4.3.3 Pollutant loads of effluent from different types of products

The effluent from different dairy products on pollutant loads is shown in Table 4.4. The differences in the pollutant loads from different dairy products was highly significant ($P < 0.001$). Effluents from fruit juices recorded the lowest ($P < 0.05$) measurement, with the exception of pH which was the highest ($P < 0.05$). The COD was highest in cheese effluent ($P < 0.05$) and decrease sequentially for the following products: milk, yoghurt and sour milk. Milk, yoghurt and sour milk had similar ($P > 0.05$) concentrations of chlorides, fluoride concentration, suspended solids, total hardness and total coliform which were all lower ($P < 0.05$) than cheese. Nitrates/nitrite concentration were highest in sour milk effluent but sequentially decreased ($P < 0.05$) in the following products: cheese, milk, and yoghurt effluents. Sulphate concentrations decreased ($P < 0.01$) from cheese, through milk, yoghurt to sour milk effluents. Colour unit, dissolved calcium, and dissolved magnesium were high ($P < 0.05$) in cheese than yoghurt and sour milk. Total dissolved solids were highest ($P < 0.01$) in cheese followed by milk, yoghurt and sour milk in that order. Effluents from sour milk had higher ($P < 0.05$) pH than milk, yoghurt and cheese effluents, in this order. Turbidity was higher ($P < 0.05$) in sour milk followed by cheese, milk and yoghurt effluents in that order. High ($P < 0.001$) total coliform count were obtained on yoghurt, mass, milk and fruit blends.

4.3.4 Pollutant loads of effluent from pasteurizer cooling machines

Table 4.5 shows the effect of size on pasteurizer cooling machine effluent. The size of the company had high impact ($P < 0.001$) on pasteurizer cooling machine effluent. The concentration of nitrate/nitrite increased ($P < 0.001$) with an increase in size of the company. Medium companies followed by large and small companies, had high effect ($P < 0.001$) on COD, suspended solids, colour, fluoride concentration, pH level, turbidity and total coliform counts. Chloride concentration,

Table 4.4: Effect of type of dairy products on pollutant loads of effluents

Source	Type of product					SE	Significance
	Cheese	Milk	Yoghurt	Sour milk (Maas)	Fruit juice		
Chemical oxygen demand (mg O ₂ /l)	8552.1 ^e	4789.5 ^d	3035 ^c	2171 ^b	21.8 ^a	512.9	***
Suspended solids at 105°C (mg/l)	2034.8 ^c	822.1 ^b	830.1 ^b	830.1 ^b	10.3 ^a	101.1	***
Nitrate/ Nitrite concentration (mg/l)	0.7 ^d	0.27 ^c	0.08 ^b	1.3 ^e	0.03 ^a	0.03	***
Chloride (mg/l)	178.3 ^c	91.4 ^b	92 ^b	92.2 ^b	5.2 ^a	6.92	***
Colour (mg Pt-Col/l)	26.2 ^d	17.8 ^b	22.5 ^c	21.8 ^c	1.6 ^a	1.03	***
Dissolved calcium (mg/l)	57.3 ^d	36.8 ^b	43.7 ^c	43.7 ^c	6.3 ^a	2.25	***
Dissolved magnesium (mg/l)	6.2 ^d	4.43 ^b	5.6 ^c	5.61 ^c	2.75 ^a	0.27	***
Fluoride concentration (µg/l)	1895.1 ^d	1007.2 ^b	1092.6 ^c	1092.6 ^c	100.8 ^a	74.7	***
pH at 25°C	3.75 ^a	4.37 ^b	4.2 ^b	5.9 ^c	7.58 ^d	0.18	***
Sulphate concentration (mg SO ₄ /l)	13.5 ^c	8.18 ^b	7.69 ^b	4.65 ^a	4.58 ^a	0.68	***
Total dissolved solids at 180°C (mg/l)	4054.6 ^d	1228.3 ^c	547.1 ^b	211.4 ^a	63.1 ^a	266.28	***
Total hardness (CaCO ₃)	167.2 ^c	92.3 ^b	92.7 ^b	92.7 ^b	28.4 ^a	6.42	***
Turbidity (NTU)	2442 ^d	1073.6 ^c	933.8 ^b	5512 ^e	0.47 ^a	115.4	***
Total coliform (cfu/100ml)	14 788 ^b	8155 ^a	8347 ^a	8334 ^a	8339.4 ^a	569.7	***

^{abcde} Values in the same row with different superscripts differ (P<0.05).

***P<0.001

Table 4.5: Effect of size of the company on effluent from pasteurizer cooling machine

Parameter	Size of company			SE	Significance
	Small	Medium	Large		
Chemical oxygen demand (mg O ₂ /l)	20.4 ^a	26.8 ^c	24.7 ^b	0.49	***
Suspended solids at 105°C (mg/l)	21.1 ^a	45.6 ^c	34.1 ^b	34.1	***
Nitrate/ Nitrite concentration (mg/l)	0.08 ^a	0.8 ^b	0.86 ^c	0.01	***
Chloride concentration (mg/l)	175.4 ^c	13.1 ^a	94 ^b	0.36	***
Colour (mg Pt-Col/l)	1.15 ^a	2.4 ^c	1.5 ^b	0.14	***
Dissolved calcium (mg/l)	83.9 ^c	8.32 ^a	45.3 ^b	0.4	***
Dissolved magnesium (mg/l)	27.5 ^c	1.1 ^a	15.1 ^b	0.4	***
Fluoride concentration (µg/l)	410.7 ^a	439.9 ^c	424.5 ^b	0.8	***
pH at 25°C	6.7 ^a	7.74 ^c	7.26 ^b	0.05	***
Sulphate concentration (mg SO ₄ /l)	133 ^c	7.7 ^a	71.3 ^b	0.6	***
Total dissolved solids at 180°C (mg/l)	661.5 ^c	61.9 ^a	361.4 ^b	0.76	***
Total hardness (CaCO ₃)	323.8 ^c	25 ^a	174.7 ^b	0.4	***
Turbidity (NTU)	0.7 ^a	5.3 ^c	4.3 ^b	0.4	***
Total coliform (cfu/100ml)	14.2 ^a	2412.1 ^c	1221.2 ^b	6.2	***

^{abc} Values in the same row with different superscripts differ ($P<0.05$)

*** $P<0.001$.

dissolved calcium, dissolved magnesium, sulphate concentration, TDS and total hardness was higher ($P<0.001$) in small than large companies.

4.3.5 Effluent mixture of the company

The effluent mixture of the company before and after treatment is shown in Table 4.6. Effluent had high pollutant loads before water treatment. The effect of treating water was not significant ($P>0.05$) on suspended solids, fluoride and pH level. The COD, nitrate/nitrite concentration, chloride concentration and colour units were affected ($P<0.05$) by treatment of waste water. Dissolved calcium, dissolved magnesium, sulphate concentration, total hardness, turbidity and total coliform were also affected ($P<0.01$) by treatment of waste water. The effect of waste water treatment on TDS was, however, highly ($P<0.001$) effective in reducing pollutant loads.

4.3.6 Effect of location on effluent pollutant loads

The effect of location on dairy effluents pollutant loads is shown in Table 4.7. Effect of location was not significant ($P>0.05$) on pollutant across provinces. Location of company had no effect on most of the parameters assessed, except fluoride concentrations ($P<0.05$). The Eastern Cape had high concentration of fluoride followed by Gauteng Province, KwaZulu-Natal and Limpopo Provinces. Free State Province had the least ($P<0.05$) fluoride concentrations.

Table 4.8 shows effluents from Western Cape which had too high pollutant loads compared to other provinces. The division of location within Western Cape Province into east and west coast region was done to get more accurate data. The effect of region within the province on pollutant loads was not significant ($P>0.05$). The effect of location however on fluoride within the province was

Table 4.6: Effect of waste water treatment on pollutant loads

Parameter	Effluent mixture		SE	Significance
	Before treatment	After treatment		
Chemical oxygen demand (mg O ₂ /l)	10202.2 ^b	1940.5 ^a	2630.2	*
Suspended solids at 105°C (mg/l)	5822.3	460.7	2607.6	NS
Nitrate/ Nitrite concentration (mg/l)	5.8 ^a	13.4 ^b	2.6	*
Chloride concentration (mg/l)	368.9 ^b	113.2 ^a	163.7	*
Colour (mg Pt-Col/l)	206.6 ^b	27.9 ^a	54.8	*
Dissolved calcium (mg/l)	133.8 ^b	39.9 ^a	23	**
Dissolved magnesium (mg/l)	21.2 ^b	9.2 ^a	2.8	**
Fluoride concentration (µg/l)	2660.7	1669	450.5	NS
pH at 25°C	7.7	7.0	0.5	NS
Sulphate concentration (mg SO ₄ /l)	53.8 ^b	7.0 ^a	27.1	**
Total dissolved solids at 180°C (mg/l)	3925.8 ^b	1101.4 ^a	566	***
Total hardness (CaCO ₃)	418 ^b	130.7 ^a	67.4	**
Turbidity (NTU)	2969.5 ^b	585 ^a	580	**
Total coliform (cfu/100ml)	36838.9 ^b	1233.6 ^a	9433.1	**

^{ab} Values in the same row with different superscripts differ ($P<0.05$)

* $P<0.05$, ** $P<0.01$, *** $P<0.001$, NS – not significant ($P>0.05$).

Table 4.7: Effect of location on dairy effluent pollutant loads

Source	Province					Significance
	KwaZulu-Natal	Limpopo	Free State	Eastern Cape	Gauteng	
Chemical oxygen demand (mgO ₂ /l)	4166 ± 1376.3	9682 ± 3554	4202 ± 2326	2774 ± 2176	4301 ± 3554	NS
Suspended solids at 105°C (mg/l)	1472 ± 498.8	1233 ± 910.6	1225 ± 596.1	855.5 ± 557.6	1283 ± 910.6	NS
Nitrate/ Nitrite concentration (mg/l)	5.1 ± 2.4	0.05 ± 7.5	9.0 ± 4.0	4.7 ± 3.8	0.5 ± 6.1	NS
Chloride concentration (mg/l)	109.3 ± 59.0	9 ± 186.4	70.9 ± 70.5	242.5 ± 66.0	264.7 ± 107.7	NS
Colour (mg Pt-Col/l)	40.1 ± 159	624.7 ± 225	73.5 ± 160.4	35.1 ± 150	694.7 ± 245	NS
Dissolved calcium (mg/l)	31 ± 10.3	62.3 ± 14.5	28.16 ± 12.1	36 ± 11.3	65 ± 18.5	NS
Dissolved magnesium (mg/l)	11.9 ± 3.3	10 ± 4.5	9.7 ± 3.5	12.7 ± 3.3	13 ± 5.3	NS
Fluoride concentration (µg/l)	1236 ± 1348 ^{ab}	2231 ± 1212 ^b	171.4 ± 1120.5 ^a	4256 ± 1048 ^c	2433 ± 1412 ^b	*
pH at 25°C	6.8 ± 0.6	6.2 ± 1.5	8.4 ± 1.0	9.1 ± 0.9	6.3 ± 1.5	NS
Sulphate concentration (mg SO ₄ /l)	46.2 ± 22.0	7.3 ± 69.6	41.2 ± 37.2	72.2 ± 34.8	79.4 ± 56.8	NS
Total dissolved solids at 180°C (mg/l)	4223 ± 1342	264 ± 2124	1938 ± 11.35	2409 ± 1062	1886 ± 1734	NS
Total hardness (CaCO ₃)	91.9 ± 0.62	135.8 ± 0.62	273.9 ± 0.62	273.9 ± 0.62	273.9 ± 0.62	NS
Turbidity (NTU)	1881 ± 659.6	422.5 ± 1745	1794.9 ± 932.7	1199 ± 873.0	1494 ± 1425	NS
Total coliform (cfu/100ml)	257.3 ± 3027	1026.3 ± 4020	60 ± 7464	287.3 ± 3047	8086 ± 4310	NS

^{abc} Values in the same row with different superscripts differ (P<0.05)

*P<0.05, NS – not significant (P>0.05).

Table 4.8: Dairy effluent pollutant loads from West and East Coast of Western Cape

Parameters	Region		SE	Significance
	West Coast	East Coast		
Chemical oxygen demand (mg O ₂ /l)	4814	27658.2	11427.9	NS
Suspended solids at 105°C (mg/l)	2021	20489.3	12454.9	NS
Nitrate/ Nitrite concentration (mg/l)	0.18	1.3	0.6	NS
Chloride concentration (mg/l)	491	1745.2	701	NS
Colour (mg Pt-Col/l)	179.7	94.2	111	NS
Dissolved calcium (mg/l)	128.9	121.2	57.8	NS
Dissolved magnesium (mg/l)	24.2	15.8	8.53	NS
Fluoride concentration (µg/l)	885 ^a	3366.6 ^b	637.91	*
pH at 25°C	7.0	5.7	0.9	NS
Sulphate concentration (mg SO ₄ /l)	56.1	65.7	23.9	NS
Total dissolved solids at 180°C (mg/l)	20902.5	5628.0	2111.5	NS
Total hardness (CaCO ₃)	428.8	355.3	174.2	NS
Turbidity (NTU)	1161.5	6580.8	2291.5	NS
Total coliform (cfu/100ml)	45571.7	56459	38394.4	NS

^{ab} Values in the same row with different superscripts differ (P<0.05)

*P<0.05, NS – not significant (P>0.05).

significant ($P>0.05$). Fluoride concentration from the east coast region was high ($P<0.05$) than fluoride concentration from west coast region.

4.4 Discussion

The aptitude of standard deviation for effluents pollutant loads to be higher than the means except for dissolved magnesium and pH indicates a high variation of pollutant loads from the mean. This could be caused by high variety of products, stage of processing and size of company (FAO, 1996). Samples of the study were collected from different sources of effluent which includes: effluents from products, washing effluents and effluent mixtures. Therefore, all these sources had different levels of pollutant load which might have caused the variation to be high.

The water standards of livestock for total coliform should be less than 10 CFU/100 ml (Higgins *et al.*, 2008). Having high mean for COD and total coliform on a current study indicates that the samples had higher counts of bacteria. Higgins *et al.* (2008) describe salinity as a dissolved material proportion of suspended solids, sulphate concentration, TDS, calcium, magnesium and silica. The high means for suspended solids, sulphate concentration, TDS, dissolved calcium and dissolved magnesium proves that effluents had high salinity. The ability of variation for pH to be closer to the pH standards (6.5-8.5) for water shows that effluents had adequate pH for consumption by animals (National Research Council (NRC), 1998). A high total hardness concentration of effluent is due to high concentration of calcium and additional magnesium of effluents (Higgins *et al.*, 2008). The high levels of nitrate/nitrite give an implication that the effluents were toxic. The ability of total coliform for washing equipment to increase with an increase in size of the company could be caused by different volume of products, processes of product, and equipment used. In large companies, most of dairy commodities are produced. This

includes chocolates, yoghurt, sour milk, pasteurized milk, UHT milk, sour cream and cheese of which some of these products are not processed in small companies (FAO, 1996). Raw milk had 100 counts which double up every 20 minutes after milk collection if milk is not kept at low temperatures (WRC, 1989; Singh, 2014). Therefore, during cleaning, the total coliform will be high especially when exposed to higher temperatures but varying with product made.

The equipment used to process products varies in size (FAO, 1996). The milk tank for holding milk and pasteurizer machine used in large companies is huge in volume compared to the small companies (WRC, 1989). Therefore, during washing, the equipment will generate high pollutant loads in accordance with size of the company. This is caused by withheld or loose substances on equipment or milk collecting pipes due to lack of hygiene (Winward *et al.*, 2008). This is where a bacteria develops in numbers, moreover, after removal due to washing, its concentration increase up which then contributes to high counts of coliform (Winward *et al.*, 2008). The time frame as well contributes, the longer it takes to dispose waste water during storage the higher the counts.

The effect of small companies on the concentration of dissolved calcium, dissolved magnesium, fluoride, pH, TDS, total hardness and colour could be linked with cleaning procedures (FAO, 1996). The cleaning processes used by small companies are not appropriately performed as in big or medium companies although the scales use the similar source of detergents which caustic and acid for cleaning (WRC, 1989). Large companies must be accredited by quality assurance accreditations including ISO standards for them to operate (Griffiths, 2010). This means large companies cleaning procedures and operation must be on high standards as compared to small companies. The findings of the current study also shows that hygiene in small companies is not

practiced adequately. The WRC (1989) reported a 2000 mg/l COD for small companies while on the current study COD was 3350 mg/l. This shows that cleaning management has previously been inadequate, hence is has not changed yet.

The mixture of different sources for effluent to affect the colour of washing equipment effluents was expected. The high unit of colour in small companies gives an indication that waste water from that sector has got more solids. An increase in concentration of TDS on the other hand was caused by cleaning detergent. Most dairy processing plants use caustic soda which consists of sodium chloride for cleaning (WRC, 1989). An increase in concentration of sodium chloride due to cleaning lead to increased levels of TDS (Higgins *et al.*, 2008). Also the contamination by organic material due to ground water adds towards the increase of TDS concentration since TDS is a sum for all organic and inorganic material (Navaratnasamy *et al.*, 2004). The discharge of nutrients from soil results in an addition of salts on ground water which is likely to increase hardness concentration.

Different products on the current study have reflected different pollutant loads levels. These findings correspond with the findings observed by Strydom *et al.* (1997). The findings have indicated that cheese has high pollutant loads mostly total coliform and COD. Strydom *et al.* (1997) reported a COD value per month of 5340 mg/l while WRC (1989) reported a COD value of 2 400 kg/month for cheese. This shows that cheese COD has dramatically changed over the years. This could be related to the changes in type of cheese produced as they come in variety with different processing and type of milk source used (FAO, 1996). The changes in COD for cheese is also observed in raw milk/pasteurized milk. Water Research Commission (WRC)

(1989) reported a COD value of 5 600 kg/month, while Strydom *et al.* (1997) reported a COD value per month of 4735 mg/l which is equivalent to the current study. The change in COD for milk over the years reflect that the quality of milk, hygiene management and equipment used to process milk has been improved in order to produce high quality products.

There has been a significant change in COD and TDS for fruit juice over the past years. Water Research Commission (WRC) (1989) reported a value of 7000 kg/month which is significantly different to the current study. This could be related with the tightening of the legislation and the laws within the fruit industry. This includes the use of high quality fertilizers and using pesticides that won't damage the fruit in order to reduce unwanted substances. The improvements in storage conditions such as storing tropical fruits like oranges at a temperature of between 0 and 9°C for 56 to 84 days and proper sanitization of fruit before delivery could also be the cause (FAO, 2013). The improvements in handling and storing fruits during transportation have also ensured that fruit quality is maintained until further production. The tightening of rules or scaling of incoming fruits at dairy industry to make juice has also played a significant role in maintaining high quality standards. Therefore, management in fruit juice manufacturing has played a successful role over the years hence pollutant loads are reduced.

The similarity of cultured products (yoghurt and sour milk) including milk in the concentration of suspended solids, chloride, colour, dissolved calcium, dissolved magnesium, fluoride and total hardness could be linked with common processing practice used for the products (Magee, 2005; Louw, 2007). For both products, a cultured substance is used to ferment the products in order to allow the growth of beneficial bacteria that adjust micro flora in the intestines (Magee, 2005). Therefore, the pollutant loads produced by the two products would be similar. The results for

COD and total coliform value from the current findings also evidenced that processes are similar. Although the values are different due to required amount of bacteria for the final product since products are different, their similarity indicates that processing of the products is common. The differences in pH for the two products was not expected, however, the expected results were that, the pH of the two product would be the same or similar as they both use a culture to ferment until it reach a certain level of acidity usually 4-5 (Louw, 2007; Belitz *et al.*, 2009). This could be caused by reduced amount of lactic causing bacteria as compared to yoghurt, resulting in an increased amount of pH, when comparing the total coliforms counts.

Differences in pollutant loads for cheese as compared to yoghurt and sour milk could be associated with the processing since these products are cultured product (FAO, 1996). Sour milk is produced by uncontrolled milk fermentation using naturally-occurring bacteria while yoghurt is produced by controlled milk fermentation of milk by lactic acid bacteria (WRC, 1989). Cheese on the other hand is produced by adding culture on milk and then adds rennet to coagulate and turn into curds and whey; after addition of salt, it is heated, thereafter allowing whey to drain off, of which then the cheese is stored (WRC, 1989; FAO, 1996). Therefore, the different ingredients added and procedures performed will result on different pollutant loads such as high TDS, suspended solids, dissolved calcium, hardness and fluoride concentration.

The differences in pH for cultured products was not expected since they all yield whey which is acid (Louw, 2007; Belitz *et al.*, 2009). The lower pH in cheese is caused by the type of cheese produced. Cheese comes with two types of whey, acidic whey (pH of 4.5) and sweet whey (pH of 6.5) (FAO, 1996). The findings reflect that the type of cheese whey used was acidic whey

which might have stayed a bit long time which then caused the pH to increase due to the growth of lactic causing bacteria. The pH for milk was expected to be 6.7 which do not correspond with the finding observed by van Den Berg (1961). The lower pH could be associated with high total coliform. Due to increased number of bacteria they produce (lactic acid) which then reduces the pH. Considering that raw milk itself, has 100 count of bacteria which doubles up every 20 minutes after milk collection (Singh, 2014), therefore, if waste water is not placed under cool environment, the bacteria grows which lead to a drop in pH. The high turbidity of sour milk and cheese is caused by high concentration of total suspended solids (Washington State Department of Ecology, 1990). The lower the amount of suspended solids, the less the turbidity. Having high turbidity for sour milk and cheese reflect that the products are highly cloudiness, however, the hardness of sour milk is moderate, unlike the one for cheese which is hard; this makes it to differ from the rest of the products effluents.

The ability of medium and small companies to affect COD, suspended solids, colour, fluoride, pH level, turbidity and total coli form, chloride; dissolved calcium, dissolved magnesium, sulphate, TDS and total hardness for pasteurizer cooling effluents is caused by equipment used. Small and medium companies use open system pasteurizer. This differ in size which works manually by releasing cold water into a system for boiling. Once it have high temperatures, hot water get released, then another bulk of cold water is released again for boiling (Appendix 3). The disadvantage about an open system pasteurizer is that it runs on an open environment, since it's a cooling system. Foreign object invade in water hence resulting in higher pollutant loads which is what was observed on a current study in small and medium companies. The poor sanitizing practice also have an impact in addition of pollutant loads, which is what is observed in total coliform and suspended solids in medium companies while in small companies it total

hardness, TDS, sulphate, dissolved calcium and chloride. The medium to less effect of large companies on effluents pollutant loads reflect that the automatic closed system or high temperature-short time (HTST) pasteurizer operators used there is a good system to avoid polluting water hence the sanitizing process is practiced well (Newhouse, 2010).

The water treatment used by companies is observed to be effective in reducing the pollutant loads. This is due to the treatment method used, which is chemical method used (mostly chlorine). Chemical method eliminates pollutant loads adequately hence it's the mostly widely used method in dairy industries (WRC, 1989; Winward *et al.*, 2008; Chapter 3). The lack of effect of water treatment on suspended solids indicates that the filtration method practiced by companies is poor. The possible cause to this matter could be blockage of filter by solids which then result in passing of some particle during the removal of cleaning of blocked filters. Regards to fluoride, there has been no report stating the effect of fluoride on water, environment or any disease. This which then cause companies to not pay much attention to it (NRC, 1993). Due to adequate pH for waste water, before treating, the treatment method becomes less effective.

The pollutant loads were similar across all the provinces except for fluoride concentration. The reason could be that, fluoride is the only mineral that is added to water for avoiding cavity (NRC, 1993). Therefore, it will depend on different municipalities' inclusion range on fluoride to water which could have resulted in different fluoride levels after production. The high level of fluoride in Eastern Cape, Gauteng, Limpopo, KwaZulu-Natal and East coast region of Western Cape indicates that water received on those regions are likely to have low rate of fluoride. The lack of effect for location to dairy effluents, reflect that different sizes of companies are represented

throughout the country, hence the processing is the same in accordance with the size of the company.

4.5 Conclusions

Location of the company did not affect any pollutant load parameter except in fluoride. Size of company and type of products affected effluents from washing equipment, products and pasteurizer cooling machine. Total coliform increased with size of company for wash equipment. Cheese generated high pollutant loads but low pH. Pasteurizer effluents from small and medium companies had high pollutant loads but low in nitrate/nitrite and turbidity. Therefore, there is need to explore the use of effluent from washing equipment since it generates the largest volumes. Effluent from washing equipment also had low pollutant loads, and it's potential to be used in feeding livestock, particularly pigs, need to be assessed. The effluent with low pollutant loads should, ideally, not be sent to the municipal sewer system, but should rather be re-used.

4.6 References

- Bartram, J. and Pedley, S., 1996. Water Quality Monitoring - A practical guide to the design and implementation of freshwater quality studies and monitoring programmes. United Nations Environment Program and the World Health Organization (UNEP/WHO).
- Bellack, E. and Schouboe, P. J., 1968. Rapid photometric determination of fluoride with SPADNS-zirconium lake. *Analytical Chemistry*, 30: 2032.
- Belitz, H., D, Grosch, W. and Schieberle, P., 2009. Food Chemistry 4th edition. Springer Science and Business media. Berlin, Heidelberg.

- Burns, E. R. and C. Marshall. 1965. Correction for chloride interference in the chemical oxygen demand test. *Journal of Water Pollution Control*, 37: 1716.
- Carawan, R. E., Jones, V. A. and Hansen, A. P., 1979a. Water use in a multiproduct Dairy. *Journal of Dairy Science*, 65: 1238-1242.
- Degen, J. and Nussberger, F. E., 1956. Notes on the determination of suspended solids. *Sewage Industrial Wastes*, 28: 237.
- Food Agriculture Organization of United Nations (FAO), 1996. Management of waste from animal product processing. Available at:
<http://www.fao.org/WAIRDOCS/LEAD/X6114E/X6114E00.HTM>. Date Accessed.|2013/08/11|
- Food Agriculture Organization of United Nations (FAO), 2013. Manual for preparation and sale of fruit and vegetables. Available at:
<http://www.fao.org/docrep/008/y4893e/y4893e06.htm>. Date Accessed.|2015/01/20|
- Griffiths, M., 2010. Improving the safety and quality of milk: Milk production and processing. Elsevier publishers, United Kingdom.
- Higgins, S. F., Agouridis, C. T. and Gumbert, A. A., 2008. Drinking water quality guidelines for cattle. UK Cooperative Extension Service, University of Kentucky College of Agriculture. United Kingdom.
- Ikhu-Omoregbe, D, I. O. and Masiwa, H., 2002. A postal survey of effluent generation and disposal in the Zimbabwean dairy industry. *Water South Africa*, 28: 179 – 182.
- Klyachko, Y. A., 2002. Water and Waste water treatment (Analysis of water quality). Encyclopaedia of Life Support Systems (EOLSS), Russia.

- Lachat Instruments, 1998. Determination of Total Phosphorus by Flow Injection Analysis Colorimetry (Acid Persulfate Digestion Method). Method Number 10-115-01-1-F.
- Louw, L., 2007. Put some culture into your milk. Ubisi mail. Available at: http://www.ubisimail.co.za/pdf_files/sep_07/putsomeculture.pdf. Date accessed. |2014/07/10|
- Magee, E., 2005. The Benefits of Yogurt: What's tasty, easy, and has lots of health benefits? Yogurt!WebMD, LLC. Available at: <http://www.webmd.com/diet/features/benefits-of-yogurt>. Date Accessed.|2014/12/16|
- Meade, M. D., 2005. Standard operating procedure for calibration and maintenance of pH meters. EPA/OPP Microbiology Laboratory ESC, SOP Number: EQ-01-04.
- National Research Council (NRC), 1993. Health effects of ingested fluoride. National Academy Press, Washington DC. National Sanitation Foundation International (NSF). United Kingdom.
- National Research Council (NRC), 1998. Nutrient requirements of swine (10th ed.). National Academy Press, Washington, DC. USA.
- Navaratnasamy, M., Feddes, J. J. R. and Leonard, J. J., 2004. Reusing liquid manure as a possible source of drinking water for pigs. Canadian Bio-systems Engineering, 40,
- Newhouse, D., 2010. Pasteurizer operator study guide: Reference and study guide for the HTST and Vat Pasteurizer Operator. Washington Department of Agriculture, USA.
- Rossum, J. R. and Villarruz. P., 1961. Suggested methods for turbid metric determination of sulphate in water. Journal of American Water Works Association, 53: 873.
- SAS, 2008. SAS Users Guide: Statistics, version 9.1. SAS Institute, Cary, North Carolina, United States of America.

- Singh, N. B., Singh, R. and Imam, M. M., 2014. Waste water management in dairy industry: pollution abatement and Preventive attitudes. *International Journal of Science and Environment*, 3: 672 – 683.
- Sokoloff, V.P., 1933. Water of crystallization in total solids of water analysis. *Industrial and Engineering Chemistry, Analytical Edition*, 5: 336.
- Standard Method Committee, 1998. Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, Water Environment Federation.
- Strydom, J. P., Britz, T. J. and Mostert, J. F., 1993. Effluent production and disposal in the South African dairy industry: A postal survey. *Water South Africa*, 19: 253 – 258.
- Strydom, J. P., Britz, T. J. and Mostert, J. F., 1997. Two- phase anaerobic digestion of three different dairy effluents using a hybrid bioreactor. *Water South Africa*, 23: 151- 156.
- Symons, G. E. and Morey, B., 1941. The effect of drying time on the determination of solids in sewage and sewage sludge's. *Sewage Works Journal*, 13: 936.
- U.S. Environmental Protecting Agency, 1993. Methods for Determination of Inorganic Substances in Environmental Samples. EPA-600/R/93/100 - Draft. Environmental Monitoring Systems Lab., Cincinnati, Ohio.
- van Den Berg, L., 1961. Changes in pH of milk during freezing and frozen storage. *Journal of Dairy Science*, 44: 26-31.
- Washington State Department of Ecology, 1990. A citizen's guide to understanding and monitoring lakes and streams, Chapter 3: Stream (Total suspended solids and turbidity in streams. Available at: <http://www.Ecy.wa.gov/programs/wq/plants/management/joysmanual/streamtss.html>. Date Accessed [2014/12/16].

Water Research Commission (WRC), 1989. Water and waste-water management in the dairy industry. WRC Project no 145 TT 38/89. NATSURV series no, 4. Published by the WRC, Pretoria, South Africa.

Winward, G. P., Avery, L. M., Stephenson, T. and Jefferson, B., 2008. Chlorine disinfection of grey water for reuse: Effect of organics and particles. *Water Research*, 42: 483- 491.

Chapter 5: Effect of dairy effluent on pigs performance obtained from washing tanks

Abstract

The objective of the study was to determine the effect of feeding dairy effluent from washing tanks on pig performance. Seventy two weaned male Landrace x Large White pigs were randomly assigned to treatments. Each pig was housed in an individual cage. Half of these pigs were fed on dairy effluent, while the remainder received regular reservoir water (control). The mean average water intake (ADWI) (2.48 ± 1.21 l/d), average daily feed intake (ADFI) (1.03 ± 0.31 kg/d), average daily gain (ADG) (0.53 ± 0.39 kg/d) and feed conversion ratio (FCR) (2.5 ± 0.27) were not affected by water source ($P > 0.05$). The ratio of water intake (WI) to feed intake (FI) (2.4 ± 0.72) and water intake (WI) to body weight gain (BWG) (0.8 ± 0.2) were not also affected by water source ($P > 0.05$). The ratio of WI to FI and WI to BWG, however, changed ($P < 0.05$) with week. It can be concluded that dairy effluent can be used to feed to pigs without compromising their growth performance.

Key words: bodyweight, digestibility, performance, water source

5.1 Introduction

Swine industry is known as one of the sectors within agriculture with high consumption of fresh water, mainly for washing the floor, animal cooling and drinking by animals (Muhlbauer *et al.*, 2010). Dairy industry on the other hand uses high volumes of water and generates high volumes of effluent. Strydom *et al.* (1993) reported that dairy industry ends up irrigating pastures with effluents. The risk of using dairy effluent for irrigation is pollution of ground water (Esterhuizen

et al., 2012). There is a need to identify and develop other methods by which dairy effluent could be utilized. One possible way is the use of dairy effluent to feed pigs.

Dairy effluent has high chemical oxygen demand, solids, and nitrate and sulphate concentrations. Feeding pigs on dairy effluent could be an alternative and a sustainable way to conserve water and utilize these nutrients. Due to high water consumption in the pig industry the use of dairy effluent can reduce usage of fresh water. Pigs are tolerant to high nitrate/nitrite (van Heugten, 2000), and chemical oxygen demand (COD) levels (Meek, 1996; National Research Council (NRC), 1998). Mc-Lesse *et al.* (1992) also observed an increase in water intake in pigs fed waste water. This could be linked with ability of pigs to tolerate some pollutant loads in water which minimise the depression of pigs performance. An increase in ambient temperature due to climate change and increased human population would lead to a decline in fresh water availability. Climate change is, therefore, likely to reduce easy access to water availability and to increase the cost of water. The use of a reusable source such as dairy effluent in reducing fresh water use in swine industry is needed. One possible source of dairy effluent is waste water after rinsing equipment. Dairy effluent generated from the second and third rinse (approximately 2000 mg O₂/l of COD) is low in pollutant loads, and thus could be used for drinking by pigs (Water Research Commission (WRC), 1989).

For pigs, water should have a pH of 6.5 to 8.8, 3000 ppm total dissolved solids (TDS), 100 ppm nitrate and nitrite, 1000 ppm sulphate concentrations and 0.10 ppm lead concentrations (Canadian Task Force on Water Quality, 1987). Dairy effluent pollutant loads, however, deviate from the water standard due to a variety of sources. Since effluents can be utilized by animals, there is a need to determine the effect that they might have on pigs to develop other practical

uses for them. Therefore, the objective of the current study was to determine the growth performance of pigs fed on dairy effluent from washing tanks. It was hypothesized that dairy effluent from washing tanks reduce pig performance.

5.2 Materials and Methods

5.2.1 Study site

The study was conducted at Ukulinga Research Farm located at the University of KwaZulu-Natal, Pietermaritzburg. The pig house had single heating, lighting, ventilation system, and 72 individual (1.5×1 m) cages. Each cage had a single low pressure nipple drinker.

A HOBO TEMPERATURE, RH[®], 1996 ONSET logger was used to measure the ambient temperature and relative humidity. In the pig house, temperature was maintained between 22 and 25 °C. Dairy effluent from washing bulk tanks was collected from Honey dew in Nottingham (Pietermaritzburg). The study procedure was approved by Animal Ethics Committee (Reference: 083/14/Animal) of the University of KwaZulu-Natal (Appendix 5).

5.2.2 Pigs and feeding management

Seventy two male pigs (Landrace x Large White) were bought from a local farmer after weaning, having a starting live weight of 15 ± 0.9 kg. These pigs were allowed a 10 day adaptation period. For identification purposes, pigs were ear tagged prior to the beginning of the experiment. The experiment took 38 days, including the adaptation period.

At arrival, the pigs were given stress packs to reduce level of stress due to changes in facilities. The lighting was switched on at 1700 h and switched off at 0700 h. The house was cleaned daily. All pigs were fed on a 45 % commercial diet and 55 % sunflower hulks of the total diet (Table 5.1). Water (Table 5.2) and feed was supplied *ad libitum*. Dairy effluent was analysed at Talbot Laboratories, Pietermaritzburg.

Procedures followed to analyse water are given in Table 5.3. Details on the laboratory procedures followed are given in Appendix 4.

5.2.3 Experimental design

Seventy two pigs were divided into two treatment groups. Thirty six pigs received regular reservoir water while the other half received dairy effluent. All pigs were assigned randomly to each treatment group. Each pig was individually housed.

5.2.4 Measurements

Data were collected weekly. Water intake (WI) was determined by the difference of weight of a 20 ℓ bucket of water (1kg = 1ℓ) at the beginning and at the end of the week. Average daily water intake (ADWI) was determined by dividing WI by 7. A spill tray was placed beneath each cage under the nipple drinkers to collect water spillages. A measured amount of water was placed in an open container within the pig house during the day. Water remaining in the container was subtracted from the initial amount to determine evaporation losses. The evaporation and spillage losses were subtracted from the water allocated for each pig every week to estimate water intake.

Table 5.1: Chemical composition of diet containing commercial diet and sunflower hulls for growing pigs

Chemical composition (DM basis)	g/kg
Net Energy for gain (MJ/kg)	181.0
Moisture	103.5
Dry matter	895.0
Protein	160.0
Fat	25.6
Fibre	32.0
Ash	43.6
Calcium	6.75
Phosphorus	5.00

DM – dry mater

Table 5.2: Water analysis for fresh clean water and grey water

Parameter	Units	Reservoir water	Dairy effluent
Chemical oxygen demand	mg O ₂ /ℓ	<20	2 050
Nitrate/Nitrite	mg N/ℓ	0.56	2.2
pH at 25°C	pH units	7.1	3.7
Sulphate concentrations	mg SO ₄ /ℓ	2.56	9.91
Suspended solids at 105°C	mg/ℓ	<10	131
Total coliforms	CFU/ 100 mℓ	0	0
Total dissolved solids at 180°C	mg/ℓ	119	6853

Table 5.3: Parameters analysed

Parameter	Procedure/Method	Source
Chemical oxygen demand (COD)	Closed Reflux, Titrimetric Method	Burns and Marshall (1965)
Suspended solids	Standard operating procedure	Degen and Nussberger (1956)
Nitrate/nitrite concentrations	Lachat method	Lachat Instruments (1998)
pH	Calibration method	Meade (2005)
Sulphate	Turbidimetric method	Rossum and Villarruz (1961)
Total dissolved solids (TDS)	Standard operating procedure	Sokoloff (1933)
Total coliforms	Standard operating procedure	Bartram and Pedley (1996)

Body weight gain (BWG) of the pig was determined by the difference of weight of a pig at the beginning and at the end of the week. Average daily gain (ADG) was calculated as BWG divided by 7. Feed intake (FI) was determined by a difference of feed in the trough which was weighed at the beginning and end of each week. Average daily feed intake (ADFI) was determined by dividing FI by 7. A plastic tray was placed under each trough to collect feed spillages. The feed spilled was dried, weighed and discarded daily. Weights of feed refusals and spillages were subtracted from the total amount of feed allocated to determine feed intake for that particular week. Feed conversion ratio (FCR) was determined by dividing the FI by BWG. Relative water intake to feed intake was measured by dividing WI with FI. The relative water intake to body weight was measured by dividing WI with BWG.

5.2.5 Statistical analyses

Statistical analyses of the data were performed with SAS (2008). The effect of water source and weeks was analysed using general linear model (GLM) procedures, with a repeated measure. The model used was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$$

where:

Y_{ijk} : is the dependent variable (average daily water intake, average daily gain, average daily feed intake, and feed conversion ratio)

μ : is the overall mean

α_i : effect of water source

β_j : effect of week

$(\alpha\beta)_{ij}$: interaction of water source and week

ϵ_{ijk} : unexplained random error. The Tukey test was used to separate means.

5.3 Results

5.3.1 Water intake for pigs fed dairy effluent

There was no significant effect of water source on average daily water intake (ADWI) for pigs (Figure 5.1). ADWI (2.4 ± 1.21 l/d) increased with the increase in time ($P < 0.001$). The ratio of WI to FI (2.4 ± 0.72) was not affected ($P > 0.05$) by water source (Table 5.4). Similarly, the ratio of WI to BWG (0.8 ± 0.2) was not affected by water source ($P > 0.05$). The week effect, however, was significant ($P < 0.05$) on the ratio of WI to FI and WI to BWG

5.3.2 Effect of water type on feed intake

The effect of dairy effluent on ADFI is shown in Figure 5.2. The ADFI (1.03 ± 0.31 kg/d), for pigs receiving different water sources was similar ($P > 0.05$). The effect of week was highly significant ($P < 0.001$) on ADFI. Pigs receiving dairy effluent tended to show a reduced ADFI (1.45 kg/d) in week 4.

5.3.3 Effect of water type on growth rate and feed conversion ratio

Figure 5.3 shows the effect of dairy effluent on ADG. Pigs on both treatments had similar ADG ($P > 0.05$). The ADG (0.53 ± 0.39 kg/d) increased with an increasing age ($P < 0.05$) in week. Water

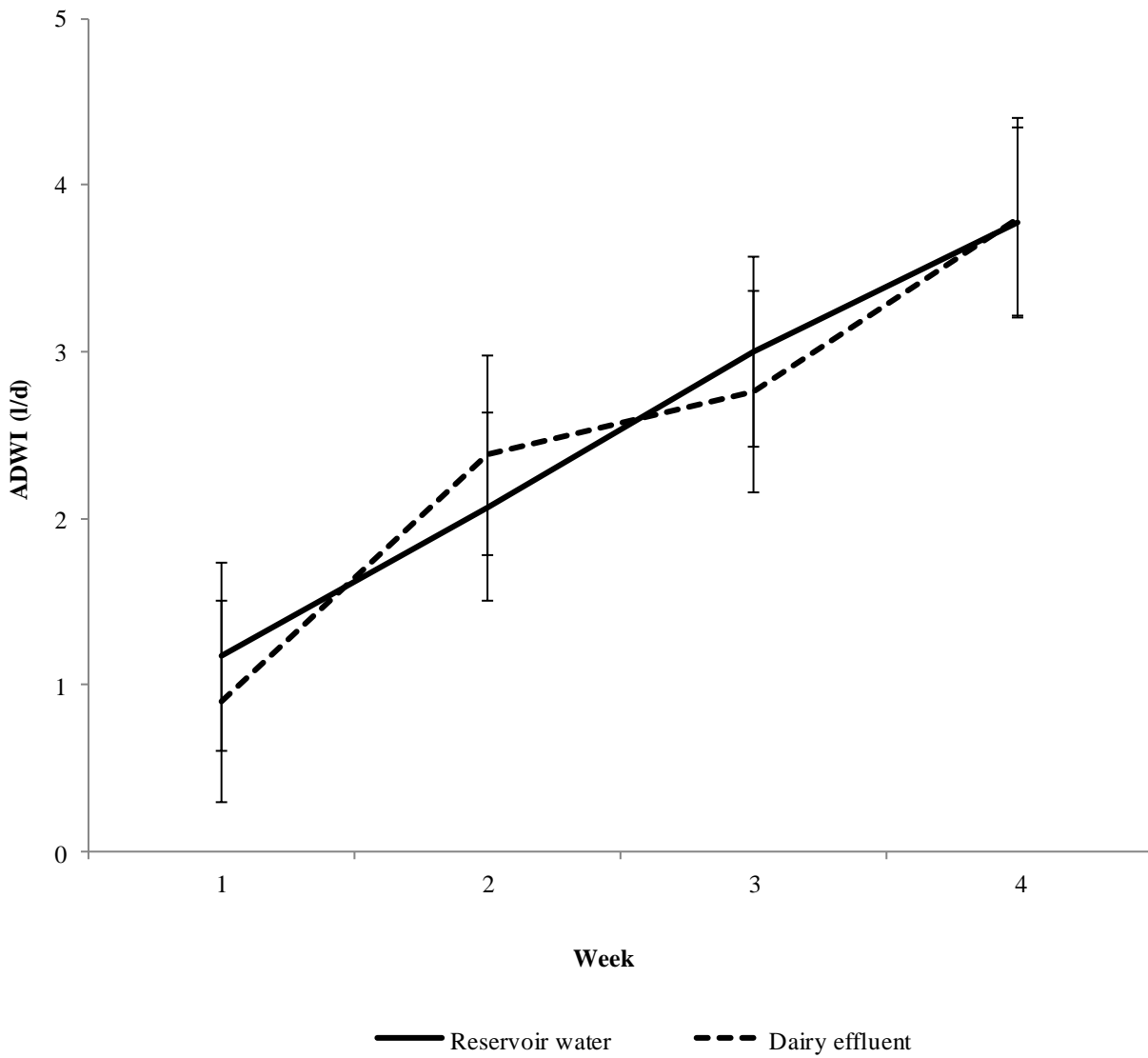


Figure 5.1: Average daily water intake (ADWI) of pigs for fed reservoir water and dairy effluent.

Table 5.4: Effect of water type on feed conversion ratio (FCR), and water intake relative to feed intake (FI) and body weight gain (BWG) of pigs

Parameter	Water type	Week				SE
		1	2	3	4	
FCR	Reservoir water	2.24 ^b	1.94 ^a	2.18 ^{ab}	2.45 ^b	0.27
	Dairy effluent	2.50 ^a	2.25 ^a	3.04 ^b	2.50 ^a	0.27
WI:FI	Reservoir water	1.65 ^a	2.87 ^b	3.19 ^b	2.53 ^b	0.72
	Dairy effluent	1.17 ^a	2.96 ^c	2.08 ^b	2.63 ^{bc}	0.72
WI:BWG	Reservoir water	0.53 ^a	0.81 ^b	0.94 ^b	0.88 ^b	0.22
	Dairy effluent	0.42 ^a	0.96 ^b	0.90 ^b	0.95 ^b	0.22

^{abc} Values in the same row with different superscripts differ (P<0.05).

SE: standard error.

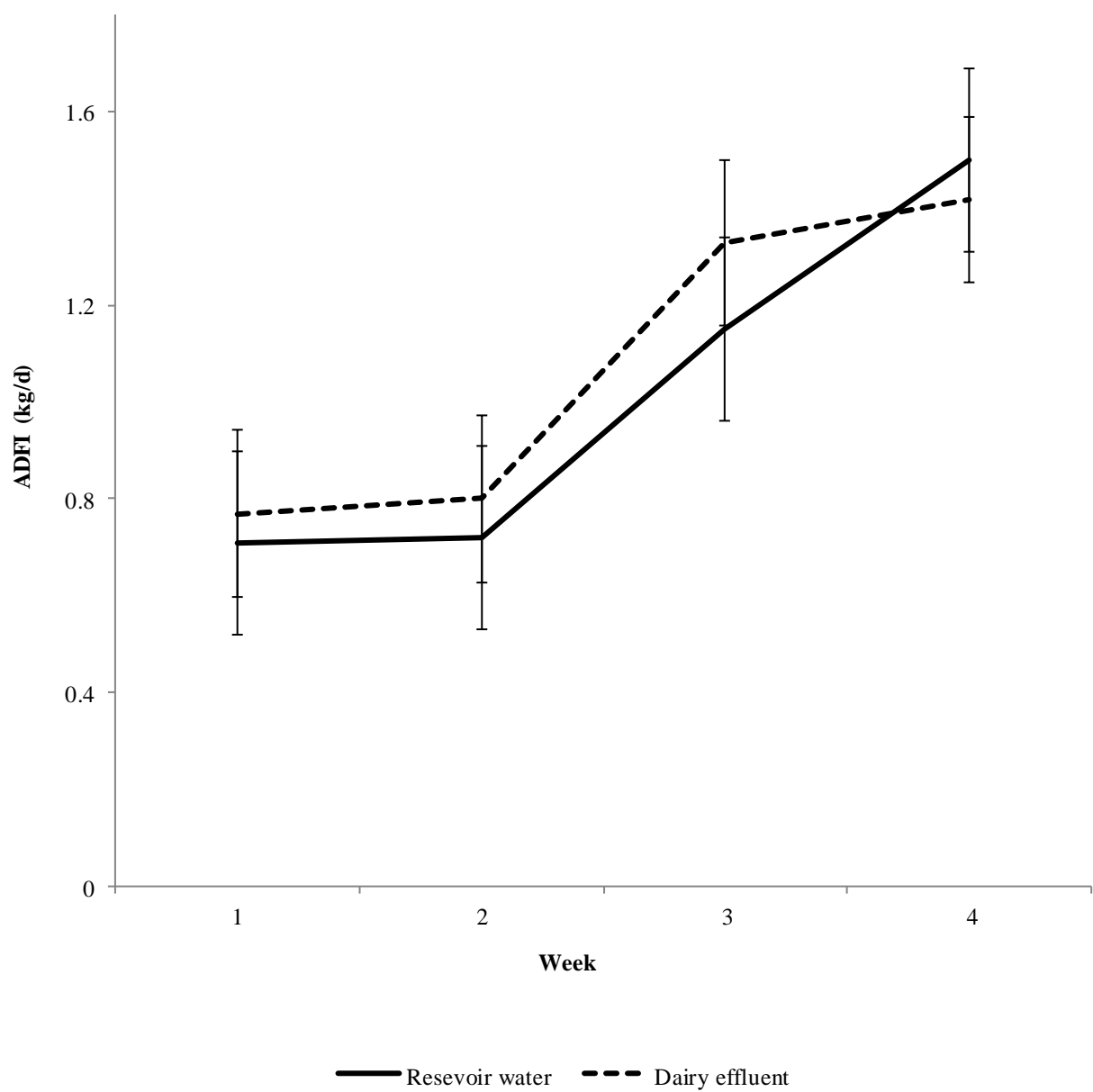


Figure 5.2: Changes in average daily feed intake (ADFI) of pigs fed on reservoir water and dairy effluent

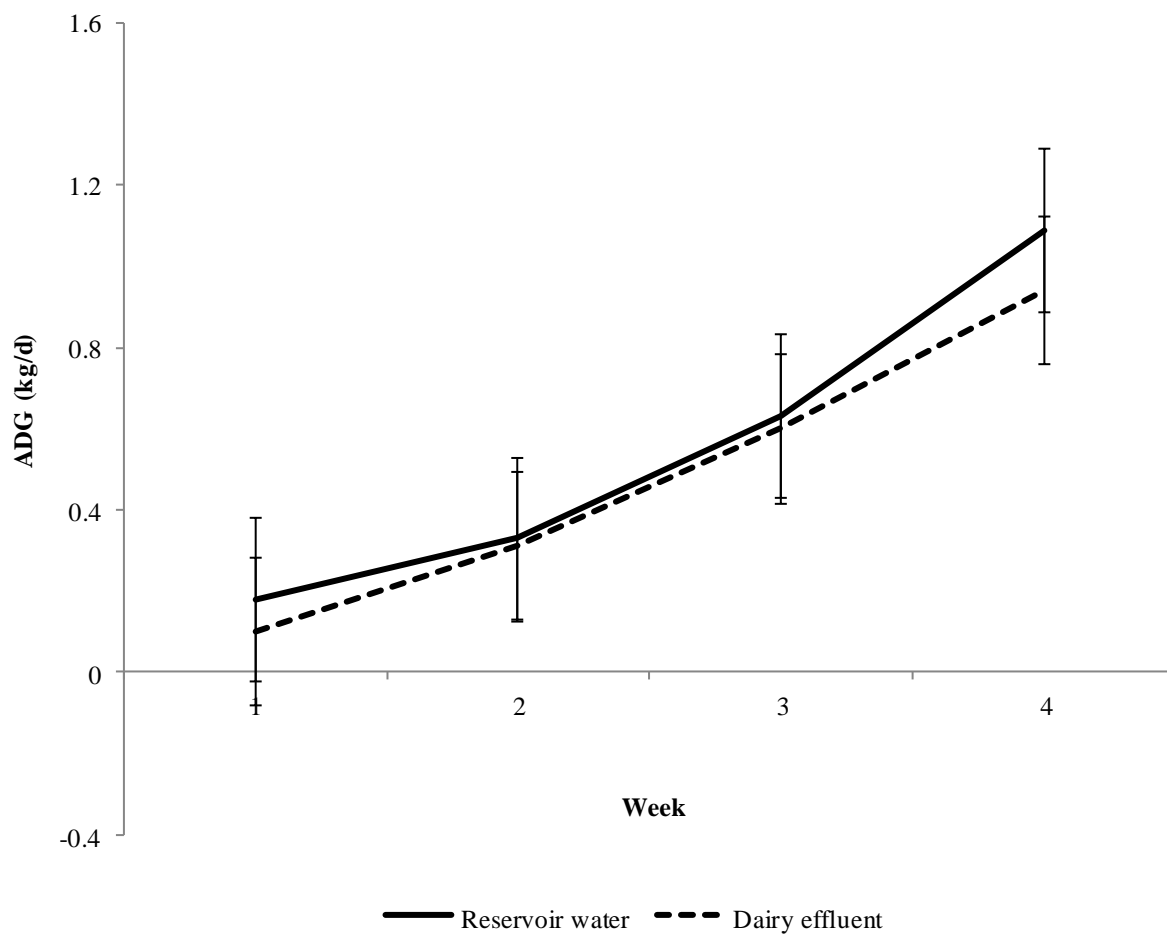


Figure 5.3: Average daily gain (ADG) of pigs fed on reservoir water and dairy effluent

source had no significant effect on FCR (2.5 ± 0.27). The FCR, however, increased with week ($P < 0.001$) (Table 5.4).

5.4 Discussion

The use of dairy effluents from washing bulk tank by pigs on a current study has shown to be less effective on pig performance, due to its low composition of pollutant loads. This is evidenced by the lack of effect of water source on ADWI. This signifies that dairy effluent from washing bulk tank is acceptable for consumption by pigs for a short term. The increase with week of water consumption could be linked with growth or increase in body weight. As pigs grow, water intakes also increase (Li and Gonyou, 2004). Water consumption for pigs on the current study ranged from 0.9 to 4 l/d. These findings were similar to the findings reported by Li and Gonyou (2004), where they reported that growing and finishing pigs consume 4.0 and 5.4 l/d of water. Most reported levels of water intake ranged from 1.9 to 6.8 l/d, depending on body weight and feed intake (Li and Gonyou, 2004). Mc-Leese *et al.* (1992) argued that pigs consume high water which leads to increased slurry volume when fed poor quality water. High fibre levels increase water holding capacity of pigs. Ngoc *et al.* (2012) also observed an increase in water holding capacity of pigs from different fibre rich sources. Pigs in this study were also fed on a high sunflower hulls diet in order to ease the mass movement of faeces in the large intestine so that water re-absorption will occur efficiently resulting in increasing water holding capacity (WHC) thus reducing watery slurry (Bakare *et al.*, 2013).

The ability of dairy effluents from washing bulk tank to be ineffective on water consumption was not expected. van Heugten (2000) reported a chemical oxygen demand COD of 100 mg O₂/l and

a pH of 6.5 to 8.5 as a safe guideline for water quality for drinking in pigs regardless of the water source. Pigs used in the current study were fed on a dairy effluent with low pH of 3.7 and high COD of 2 050 mg O₂/ℓ. Feeding pigs with water that has low pH may corrode and dissolve metals from water piping system which can result in pigs refusing to drink water due to contamination of water by metals like lead, copper or iron (Nyachoti and Kiarie, 2010). The refusal of water could also be caused by acidic condition due to poor palatability. Pigs in the current study were tolerant to the effect of pH and COD. These results agrees with Nyachoti *et al.* (2005). Anderson *et al.* (1994) on the other hand, reported that feeding pigs with water which has high levels of TDS does not reduce growth performance. Meek (1996) and National Research Council (NRC) (1998) confirmed that a total coliform (bacteria found in water) of 5000 CFU/100 ml as guideline for pigs. Although on a current study, there was no availability of total coliform, however, the ability of pigs to be tolerant to reduced water quality indicates that they can utilize dairy effluent.

The lack of water source effect on water intake was also observed on the ratio of WI to BWG and ratio of WI to FI. This indicates that dairy effluent from washing bulk tank had a positive potential effect for use by pigs. The mean ratio of water intake to feed intake on a current study was 2.4, and is close to 2.6 ratio reported by Shaw *et al.* (2006) for clean water to feed intake. Brumm (2005) also observed a similar ratio of between 2.5 and 3.5 for growing to finishing pigs. This indicated that dairy effluent had no adverse impact on the feed intake. A varying ratio of WI to FI gives an indication that pigs consumed more water per kg of feed intake as they were growing. de Lange *et al.* (2006) also reported that pigs consume 2.18 l per kg of dry mater (DM) intake. Brumm (2005), however, reported that water: feed ratio decreases as pigs grow. The variation of water: feed ratios on a current study could be linked with feed form and nutrient

digestibility. Less fibrous pelleted diets are known to have high feed intake and nutrient digestibility (Ngoc *et al.*, 2012). This is due to a high digestibility of the feed. Pigs on a current study were subjected to high fibre diet which was not pelleted. This made pigs to consume more feed in trying to meet the first limiting nutrient. An increase in feed intake is subjected to increase in water consumption.

During the growth phase, pigs require high nutrient profile for them to grow adequately. This will make them to consume more feed but drink less water as they grow due to adequate availability of nutrients. As a result, the ratio of water to feed decreases as pigs grows. In the case of the current study, the ratio of water to feed intake changed as pigs grew. This could be linked with less digestibility of fibre. A positive relationship of water source to feed intake was also observed in body weight. Pigs in this study have shown a mean ratio of 0.8 water consumption relative to body weight. When considering the final weight of pigs in week 4 (30 kg), the water consumed per 30 kg of pork produced becomes 24 ℓ. This agrees with Maynard *et al.* (1979) that from 70 to 90 % of water is consumed per lean body tissue.

The resistance of pigs to pollutant loads effect on water intake was also observed in feed intake. The interesting part comes from high salinity of dairy effluent which was expected to reduce feed intake. The high concentration for suspended solids, sulphate concentration and TDS, suggests that dairy effluents from washing bulk tank had high salinity. Higgins *et al.* (2008) reported that high saline water would reduce feed intake and growth in cattle. This agrees with Kober (1993) and NRC (1998) that high levels of TDS (1000 – 5000 mg/ℓ) would cause a refusal of water which has adverse effect on feed intake. These findings agree with Mc-Leese *et al.* (1992) who reported that high levels of TDS (4 390 mg/ℓ) will reduce feed intake.

According to the Canadian Task on Water Quality (1987) the maximum permissible TDS in clean water for pigs is 3000 mg/ℓ. In the current study, pigs on dairy effluent from washing bulk tank had up to 6 853 mg/ℓ of TDS which doubles the Canadian water standards for TDS. Water quality, however, did not affect the feed intake. This indicates that dairy effluent from washing bulk tank was acceptable for pigs without noticeable adverse effect on health. The results of the current study agree with the findings observed by Nyachoti *et al.* (2005), on pigs fed poor quality water from ground water. Therefore, considering the use of dairy effluent from washing bulk tank to pigs can be an alternative way to reduce fresh water use in swine industry. However, it could be essential to also consider the effect of dairy effluent on meat quality in order to avoid any adverse effect to human health that could be caused by water.

One might argue that the mean ADFI (1.03 ± 0.31 kg/d) of the current study was low compared to reported figures 1.5kg/d (Lammers *et al.*, 2007b), which could be linked with body weight. Pigs with high body weight consume more feed than pigs with low body weight. Pigs start the growing phase at a body weight of 25 kg until 75 kg (Lammers *et al.*, 2007b). The estimated feed intake at that weight is 1.5kg/d (Lammers *et al.*, 2007b). Pigs in this study commenced at a mean weight of 15 kg which might have caused the reduction of ADFI at the end of the trial. The lack of effect for water source on ADFI was also observed for ADG. This is caused by a direct relationship between feed intake and body weight gain (Whittington *et al.*, 2000). If water source is ineffective on feed intake, therefore, it would also be less effective on weight gain since there is a direct relationship between the two parameters.

The effect of body weight on ADFI was also observed in ADG. The mean ADG for the current study was 0.53. Most reported ADG in growing pigs is 0.75 kg/d (American Association of

Swine Veterinarians (AASV); Lammers *et al.*, 2007b). Although ADFI and ADG seem to be reduced in the current study compared to previously reported studies, the inability of water source to affect ADFI and ADG, indicate that dairy effluent is useful in pigs.

The lack of water source to affect FCR could be linked with the composition of water source. Dairy effluent includes by-product from milk processing (sweet whey, acid whey, and butter milk). These by-products improve growth rates and FCR (Lawlor *et al.*, 2002). Different authors have also indicated that using liquid by product improves animal performance (Russell *et al.*, 1996; Brooks *et al.*, 2001). A variation of FCR in relation to period (weeks) gives an indication that pigs were adapting in consuming less feed to gain more weight. The desired feed ratio reported for pigs at growing stage is 2.5 (Lammers *et al.*, 2007a). On a current study, the mean for growing pigs feed ratio was 2.4 which is close to other studies (Lammers *et al.*, 2007a). This still indicates that water source was not effective on performance parameters including FRC.

5.5 Conclusions

Dairy effluent had no effect on ADWI, ADFI, ADG and FCR for pigs. Although ratio of water in relative to FI and BWG were slightly reduced, however, the ability of pigs to tolerate effect of water source evidence that dairy effluent has high potential use in pigs. Therefore, it can be concluded that dairy effluent can be used to feed pigs without compromising their growth performance, thus the hypothesis that dairy effluent does not reduce the performance of growing pigs is accepted.

5.6 References

- Anderson, J. S., Anderson, D. M. and Murphy, J. M., 1994. The effect of water quality on nutrient availability for grower/finisher pigs. *Canadian Journal of Animal Science*, 74: 141-148.
- Bakare, A. G., Ndou, S. P. and Chimonyo, M., 2013. Influence of physicochemical properties of fibrous diets on behavioural reactions of individually housed pigs. *Livestock Science*, 157: 527-534.
- Bartram, J. and Pedley, S., 1996. *Water Quality Monitoring - A practical guide to the design and implementation of freshwater quality studies and monitoring programmes*. United Nations Environment Programme and the World Health Organization (UNEP/WHO).
- Burns, E. R. and C. Marshall. 1965. Correction for chloride interference in the chemical oxygen demand test. *Journal of Water Pollution Control*, 37: 1716.
- Brooks P. H., Beal, J. D. and Niven, S., 2001. Liquid feeding of pigs: potential for reducing environmental impact and for improving productivity and food safety. *Recent Advanced Animal Nutrition*, 13: 49-63.
- Brumm, M. C., 2005. Water systems for growing swine. *NCSU Extension Swine Husbandry*, 28 (06).
- Canadian Task Force on Water Quality, 1987. Evaluating water quality for livestock. Available at: <http://www.gov.mb.ca/agriculture/livestock/production/pork/print/evaluating-water-quality-for-livestock.html>. Access Date |23/10/2014|
- Degen, J. and Nussberger, F. E., 1956. Notes on the determination of suspended solids. *Sewage Industrial Wastes*, 28: 237.

- de Lange, C. F. M., Zhu, C. H., Niven, S., Columbus, D. and Woods, D., 2006. Swine liquid feeding: Nutritional considerations. Presented at the 2006 Western Nutrition Conference; Winnipeg, MB, Canada.
- Esterhuizen, L., Fossey, A. and Lues, J. F. R., 2012. Dairy farm borehole water quality in the greater Mangaung region of the Free State Province, South Africa. *Water South Africa*, 38: 803 - 806.
- Higgins, S. F., Agouridis, C. T. and Gumbert, A. A., 2008. Drinking water quality guidelines for cattle. UK Cooperative Extension Service, University of Kentucky College of Agriculture.
- Kober, J. A., 1993. Water: the most limiting nutrient. *Agri-Practise*, 14: 39-42.
- Lachat Instruments, 1998. Determination of total phosphorus by flow injection analysis colorimetry (Acid Persulfate Digestion Method). Method Number 10-115-01-1-F.
- Lammers, P. J., Stander, D. R. and Honeyman, M. S., 2007a. Niche Pork Production, feed budget (managing feed cost). Iowa State University, United States of America.
- Lammers, P. J., Stander, D. R. and Honeyman, M. S., 2007b. Niche Pork Production, feed and growth (nutrition). Iowa State University, United States of America.
- Lawlor, P. G., Lynch, P. B., Gardiner, G. E., Caffrey, P. J. and O'Doherty, J. V., 2002. Effect of liquid feeding weaned pigs on growth performance to harvest. *Journal of Animal Science*, 80: 1725-1735.
- Li, Y. and Gonyou, H. W., 2004. Water intake and wastage by grower/finisher Pigs at nipple drinkers. Prairie Swine Centre.

- Maynard, L. A., Loosli, J. K., Hintz, H. F. and Warner, R. G., 1979. Animal Nutrition, 7th Ed., McGraw-Hill, New York. 47-59.
- Mc-Lesse, J. M., Tremblay, M. L., Patience, J. F. and Christison, G. I., 1992. Water intake patterns in the weanling pig: effect of water quality, antibiotics and probiotics, Animal Production 54: 135- 142.
- Meade, M. D., 2005. Standard operating procedure for calibration and maintenance of pH meters. EPA/OPP Microbiology Laboratory ESC, SOP Number: EQ-01-04.
- Meek, A. J., 1996. Water quality concerns for swine. Small Farm Today. 13:15.
- Muhlbauer, R. V., Moody, L. B., Burns, R. T., Harmon, J. and Stalder, K., 2010. Water consumption and conservation techniques currently available for swine production. Research report (NPB #09-128) by Iowa State University to National Pork Board.
- National Research Council, 1998. Nutrient Requirements of Swine (10th ed.).National Academy Press, Washington, DC, United States of America.
- Ngoc, T. T., Len, N. T. and Lindberg, J. E., 2012. Chemical characterization and water holding capacity of fibre-rich feedstuffs used for pigs in Vietnam. Asian-Australasian Journal of Animal Science, 25: 861-868.
- Nyachoti, C. M. and Kiarie, E., 2010. Water in swine production: a review of its significance and conservation strategies. Manitoba Swine Seminar, 24: 217-232.
- Nyachoti, C. M., Patience, J. F. and Seddon, I. R., 2005. Effect of water source (ground versus surface) and treatment on nursery pig performance. Canadian Journal Animal Science, 85: 405-407.
- Rossum, J. R. and Villarruz. P., 1961. Suggested methods for turbid metric determination of sulphate in water. Journal of American Water Works Association, 53: 873.

- Russell, P. J., Geary, T. M., Brooks, P.H. and Campbell, A., 1996. Performance, water use and effluent output of weaner pigs fed ad libitum with either dry pellets or liquid feed and the role of microbial activity in the liquid feed. *Journal of Science Food Agriculture*, 72:8-16.
- SAS, 2008. SAS Users Guide: Statistics, version 9.1. SAS Institute, Cary, North Carolina, United States of America.
- Sokoloff, V.P., 1933. Water of crystallization in total solids of water analysis. *Indian Engeneering Chemical Analytical Edition*, 5: 336.
- Shaw, M. I., Beaulieu, A. D. and Patience, J. F., 2006. Effect of diet composition on water consumption in growing pigs. *Journal of Animal Science*, 84: 3123–3132.
- Strydom, J. P., Britz, T. J. and Mostert, J. F., 1993. Effluent production and disposal in the South African dairy industry: A postal survey. *Water South Africa*, 19: 253 – 258.
- van Heugten, E., 2000. Guidelines for water quality in pigs. *Animal Science Facts: Extension Swine Husbandry*. ANS, 00-811S.
- Veenhuizen, M. F., Shurson, G. C. and Kohler, E. M., 1992. Effect of concentration and source of sulphate on nursery pig performance and health. *Journal of American Veterinary Medical Association*, 201: 1203-8.
- Water Research Commission, 1989. Water and waste-water management in the dairy industry. WRC Project no 145 TT 38/89. NATSURV series no, 4. Published by the WRC, Pretoria, South Africa.

Whittington, D. L., Nyachoti, C. M., Patience, J. F., Gonyou, H. W., Zijlstra¹, R. T. and Lemay, S. P., 2000. Feed intake a checklist of nutritional, environmental and management strategies to achieve success. Prairie Swine Centre Inc.

Chapter 6: General Discussion, Conclusions and Recommendations

6.1 General Discussion

The dairy industry uses substantial amounts of water and consequently large volumes of effluents are produced. Appropriate disposal of effluents however, becomes a major challenge in managing to an extent that dairy effluents ends up dumped in rivers. The need of assessing water utilization and conservation in dairy industry is required so as to draw appropriate recommendations. Therefore, the main objective of the study was to assess water utilization and conservation methods used by dairy processing plants. It was hypothesized that water usage across different sizes of companies is the same, and dairy processing plants do not conserve water.

A questionnaire was used (Chapter 3) to determine water conservation strategies used in dairy processing plants, processes involved in production and their level of water consumption. The effect of size of the company on waste water generation and the treatment method used were assessed. Water use during different processes of production which includes receiving, steaming, cooling, cleaning in place and boiling differed with size of company as expected. Large companies used high levels of water compared to small companies. Most companies used dairy effluent for irrigation to conserve water. Therefore, the hypothesis that water usage across different sizes of companies is the same and dairy processing plants do not conserve water was rejected. Differences in water use during different processes were due to different products processed by different sizes of companies. Desserts and sterilized milk were produced by small and large companies. Cultured butter milk, milk powder and custard were mostly produced by large and medium companies. The use of dairy effluent for irrigation leads to recycling of

nutrient back to the soil, thus the method is cheap as compared to treating of waste water. The use of municipal water as the major water source, which was not influenced by size or location of the company showed that majority of companies have not been treating water. They rather use it for irrigation. For those companies that were treating water, chemical treatment was the most used method across sizes of companies. The need of understanding the pollutant loads generated by different size of companies which varies with water use that was high in large companies and low in small companies was essential to study. This would assist in developing other alternative use of dairy effluent other than treating it, thus reducing the cost of treating water.

In Chapter 4, the hypothesis that size of the company does not affect pollutant loads of dairy effluents was tested. The size of the company and type of products had impact on dairy effluent pollutant loads. Therefore, the impact of size and products on dairy effluent pollutant loads gave the platform to reject the hypothesis that size of the company does not affect dairy effluent pollutant loads. The rejection of hypothesis was not expected, as it was expected that pollutant loads generated from the different sizes of companies would be the same. This could be linked with different types of products being processed and different water usage in accordance with size of the company. As a result, large companies generate high volume of effluent due to huge volumes of water used which is influenced by volume of different products processed.

Chapter 4 highlighted that the dairy effluent from washing tanks had low pollutant loads and could, therefore, be considered for feeding pigs. The hypothesis that dairy effluent from washing tanks has no effect on pig performance was tested in Chapter 5. Pigs were selected for use due to their requirement for large volumes of water. The performance of pigs fed on dairy effluent was similar to those pigs fed on reservoir water. Therefore, the hypothesis that dairy effluent from

washing tanks has no effect on pig performance was not accepted. The failure of rejection of the hypothesis was not expected, as pigs are sensitive in responding to the quality of water they drink. The tolerance of pigs to dairy effluent suggests that pigs can perform on dairy effluent without their growth performance being compromised. Using dairy effluent for pig feeding should, therefore, be given serious consideration as a way of recycling dairy effluent.

6.2 Conclusions

Water use was high in large companies and low in small companies. The size of company and type of products had high impact on dairy effluent pollutant loads. Pigs fed on dairy effluent performed the same as the pigs fed on reservoir water, which suggested that wastewater does not compromise pig performance. Therefore, it can be concluded that water use and conservation in South African dairy sector is still a big issue, thus more work is required to be done in order to increase level of awareness. The use of dairy effluent to pigs could be one of the strategies of increasing level of awareness about water conservation.

6.3 Recommendations

Water use in dairy industries differs. Moreover, effluents generated also differ. There is a need to quantify specific water use and effluent generated to evaluate if water is wasted or conserved. The use of water meters in measuring water coming in and effluent coming out could be essential. The availability of information on equipment's, processes involved in specific product and water use is essential so as to quantifying the water used per specific product. The need of evaluating specific product from different sizes is essential so as to quantify water use and effluent generation of that specific product coming from different sizes. Small and medium

companies must improve hygiene management, and change their pasteurizer system into closed system in order to reduce pollutant loads. Companies should also consider constructing different drainage systems for carrying effluent from different stages of the production process.

6.3.1 Further research aspects

The following aspects require further investigation:

- Effect of location (within province) on water utilization, conservation and pollutant loads for dairy effluents
- Effect of products on dairy effluent pollutant loads from different size of company
- Effect of equipment type on dairy effluent pollutant loads
- Effect of different sources of dairy effluent from dairy processing plant on pig performance.
- Effect of time of storage of dairy effluent from dairy processing plant on pig performance and meat quality.
- Effect of dairy effluent from dairy processing plant on pig behaviour and health.
- Effect of different sources of dairy effluent from dairy processing plant on other livestock

Appendix 1: Ethical approval for survey



6 June 2014

Mr Nhakanipho Wellcome Sithole 208501007
SAEES
Pietermaritzburg Campus

Dear Mr Sithole

Protocol reference number: HSS/0240/014M

Project title: Assessment of water utilization and conservation patterns in South African dairy processing plants

Full Approval – Expedited

This letter serves to notify you that your application in connection with the above has now been granted **Full Approval**

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project; Location of the Study, Research Approach/Methods must be reviewed and approved through an amendment /modification prior to its implementation. Please quote the above reference number for all queries relating to this study. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

Best wishes for the successful completion of your research protocol

Yours faithfully


.....
Dr Shenuka Singh (Chair)
Humanities & Social Science Research Ethics Committee

/pm

cc Supervisor: Professor Michael Chimonyo
cc Academic Leader: Dr O Mutanga
cc School Admin: Ms Marsha Manjoo

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Appendix 2: Survey questionnaire

Conserving water on Dairy Industry

The Water Research Commission in conjunction with the University of KwaZulu-Natal and University of Stellenbosch is conducting a research on, waste water management. They wish to investigate the ways in which waste water such as grey water could be utilised as a part of conserving water in dairy industry.



The aim of the study is to find ways on which waste water, such as grey water from dairy, could be utilized. South Africa has been regarded as one of the top countries to produce milk in the African continent and also one of the leading countries facing water shortage. As a leading country in dairy production, the country should also be leading with water conservation for Africa. Therefore, the study will develop strategies and recommendation for waste water utilization and reduce the use of fresh water, hence increasing fresh water availability.

The study is in a survey format and the data will be collected through a questionnaire. We ask for your help to answer the questions of the survey. All data collected from this study will be confidential and only be used as part of this research project. Please be advised that if you feel like dropping from participating, you are free to do so.

I, (name) hereby confirm that the questionnaire has been clearly explained to me and I understand the purpose of this study.

I therefore agree to voluntarily participate in this research study.

.....
Signature

.....
Date

Section A. General Introduction of the company

For the following questions please mark with x on the box unless you're given instructions

1. Location of the company (Province)

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

2. Period the company has been in operation

< 10 years		10 - 20 years		> 20 years	
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3. Perceived size of the company

Small Scale		Medium Scale		Large Scale	
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4. What do you consider as main products that you produce?

Pasteurised milk		Processed cheese		butter	
UHT milk		Whey powder		custards	
Sterilised milk		Cultured butter milk		Soft and hard cheese	
Evaporated milk		Butter milk powder		yoghurt	
Condensed milk		Evaporated whey		desserts	

Milk powder		Whey powder		Maas	
Low fat milk		Fruit juice blends		Sour cream	
High fat milk		Pasteurised cream		Fruit juice	
Other <i>(please specify)</i>					

5. What are other products being processed by the company?

Pasteurised milk		Processed cheese		butter	
UHT milk		Whey powder		custards	
Sterilised milk		Cultured butter milk		Soft and hard cheese	
Evaporated milk		Butter milk powder		yoghurt	
Condensed milk		Evaporated whey		desserts	
Milk powder		Whey powder		Maas	
Low fat milk		Fruit juice blends		Sour cream	
High fat milk		Pasteurised cream		Fruit juice	
Other <i>(please specify)</i>					

Section B. Processing

6. How much milk do you receive per day?

< 10 kℓ.d ⁻¹		10 – 50 kℓ.d ⁻¹		50– 200 kℓ.d ⁻¹	
200 – 400 kℓ.d ⁻¹		400 – 900 kℓ.d ⁻¹		> 900 kℓ.d ⁻¹	

7. How much water do you use per month?

< 20 kℓ		20 – 100 kℓ		100 – 400 kℓ	
400 – 1000 kℓ		1000 – 2000 kℓ		> 2000 kℓ	

8. How much is the cost of electricity per month?

< R6 450 kWh		R6 450 – 9 675 kWh		R9 675 – 12 900 kWh	
R12 900 - 19 350 kWh		R19 350 - 25 800 kWh		> R25 800 kWh	

9. Where do you, mostly use water?

1 = very high; 2= high; 3 = intermediate ; 4 = low, 5= very low, 6= none

Receiving		Filling room		Boiling	
Steaming		Cooling		Cold storage	

Cleaning

10. What time of a day does most cleaning takes place?

Morning		Afternoon		Evening	
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11. How frequently do you do thorough cleaning?

Every day		Once a week		Twice a week	
Three time a week		Once a month		Twice a month	

12. How is water consumed for cleaning from the following stations?

1 = very high; 2= high; 3 = intermediate; 4 = low, 5= very low, 6 = none

Receiving		Filling room		Boiling	
Steaming		Cooling		Cold storage	
Packaging		Case washer and Garage (car wash)			

13. What is your source of water for cleaning?

Tab water		Recycled water		Bore water	
Rain water		River water		Fountain water	

14. What is your source of water for cleaning used for?

Cleaning floor		Washing crates and bottles		Cleaning tanks	
Washing equipment		Washing car and trucks			

Pollutant Effluent

15. Do you treat water before disposal?

Yes		No	
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If answered no skip to no. 19

16. If yes, how do you treat water?

Biologically		Chemically		Physically	
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17. What type of water do you treat?

Wastage of milk and milk product		Water from washing of crate and bottles		Water from carton filling	
Water from vehicle washing		Water from cleaning in place			

18. Which of the following water treatment is costly?

1 = very high; 2= high; 3 = intermediate; 4 = low, 5= very low

Wastage of milk and milk product		Water from washing of crate and bottles		Water from carton filling	
Water from vehicle washing		Water from cleaning in place			

19. What type of water is used for the following?

1 = Wastage of milk and milk product; 2= Water from washing of crate and bottles; 3 = Water from carton filling; 4 = Water from vehicle washing, 5= Water from cleaning in place, 6= all of above

Irrigation		Filter bed		Ponds	
Chickens		Municipal sewage		Rivers	

20. Has water costs change over the last 10 years?

No change		Small change	
Intermediate change		Large change	

21. Has electricity costs change over the last 10 years?

Yes		No	
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If answered no skip to no. 23

22. If yes, how frequently has the change occurred?

Small change		Intermediate change		Large change	
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23. Which is more expensive between electricity and water?

Electricity		Water	
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Section C. Water conservation patterns

For the following questions please mark with x on the box unless you're given instructions

24. Do you conserve water?

Yes		No	
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If answered yes skip to no 26.....

If answered no, answer no 25 and skip to no 31

25. If no, what hinders you from conserving water?

Lack of information		Lack of management		Less water usage	
Lack of Capital		Less waste water production		Lack of skilled labour	
Other (please specify)					

26. If yes, which water conservation strategies are you using?

Cleaner production		Water pinch		Life cycle assessment	
Used for broiler feed		Grey water use		Irrigation	
Other (please specify)					

27. Are you happy with the water conservation strategies you are using?

Yes		No	
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28. How long have you been using your water conservation strategy?

< 10 years		10 – 20 years		> 20 years	
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29. How successful have the strategies been?

Less successful		Moderate successful		Very successful	
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30. How did you learn about them?

Journals/books		Agricultural advisor /		Conference/	
Newspaper /internet		friend/ colleagues		meetings	
Other (please specify)					

31. Are there other strategies to conserve water that you are planning to implement?

Yes		No	
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If answered no skip to question 33

32. If yes, in which of the following do you consider to use?

Cleaner production		Water pinch		Life cycle assessment	
Used for broiler feed		Grey water use		Irrigation	
Other (please specify).....					

33. If no, what hinders you from planning to implement other strategies?

Lack of information		Lack of management		Less water usage	
Lack of Capital		Less waste water production		Lack of skilled labour	
Other (please specify).....					

34. Do you capture evaporated water?

Yes		No	
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If answered no skip to question 36

35. If yes, what do you use the evaporated water for?

Recycling		Toilet flushing/Irrigation		Animal feed/ drinking	
Other <i>(please specify)</i>					

36. If no, for what reason you don't capture it?

Too polluted		Expensive to capture		Lack of knowledge	
Lack of skilled labour in handing		Lack of equipment to re-use		Difficult to capture	
Other <i>(please specify)</i>					

37. What are some of the challenges that you face regarding water usage?

Lack of skilled labour		Lack of management		Leakages	
Other <i>(specify)</i>					

38. How often do you monitor leakages and water wastage?

Very often		Not really		Some times	
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39. Does management discuss strategies of conserving water?

Yes		No	
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If answered no skip to question 41

40. If yes, how often do they discuss?

Very often		Not really		Some times	
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41. If no, what hinders them from discussing?

Lack of knowledge		Shortage of time due to lot of commitment		Satisfied with current water consumption	
Other (<i>please specify</i>)					

42. Are you aware about water conservation?

Yes		No	
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If answered no skip to question 44

43. If yes, why do you think it should be conserved?

Increase water availability		Reduce cost		Future use	
Other (<i>please specify</i>)					

44. If no, what do you think hinders you to be aware?

Lack of knowledge		Lack of interest		Lack of access to water usage information	
Other (<i>please specify</i>)					

!!!!!! Thank you for your contribution!!!!!!

Appendix 3: Pasteurizer system used in different sizes of companies



a. open system pasteurizer cooling machine used in small companies



b. The closed system cooling pasteurizer machine used in large companies

Appendix 4: Methods of determining pollutant loads of dairy effluents

1. Determination of Chemical Oxygen Demand (COD) using closed reflux, titrimetric method

Wash culture tubes and caps with 20% H₂SO₄ before first use to prevent contamination. Make volumetric measurements as accurate as practical; use Class A volumetric ware. The most critical volumes are of the sample and digestion solution. Use a microburet for titrations. Measure H₂SO₄ \pm 0.1 ml. The use of hand-held pipettes with non-wetting (polyethylene) pipet tips is practical and adequate. Place sample in culture tube or ampule and add digestion solution. Carefully run sulphuric acid reagent down inside of vessel so an acid layer is formed under the sample-digestion solution layer.

Tightly cap tubes or seal ampules, and invert each several times to mix completely. CAUTION: *Wear face shield and protect hands from heat produced when contents of vessels are mixed. Mix thoroughly before applying heat to prevent local heating of vessel bottom and possible explosive reaction.*

Place tubes or ampules in block digester preheated to 150°C and reflux for 2h behind a protective shield. CAUTION: *These sealed vessels may be under pressure from gases generated during digestion. Wear face and hand protection when handling. If sulphuric acid is omitted or reduced in concentration, very high and dangerous pressures will be generated at 150°C.*

Cool to room temperature and place vessels in test tube rack. Some mercuric sulphate may precipitate out but this will not affect the analysis. Remove culture tube caps and add small TFE-

covered magnetic stirring bar. If ampules are used, transfer contents to a larger container for titrating.

Add 0.05 to 0.10 mL (1 to 2 drops) ferroin indicator and stir rapidly on magnetic stirrer while titrating with standardized 0.10M FAS. The end point is a sharp colour change from blue-green to reddish brown, although the blue-green may reappear within minutes. In the same manner reflux and titrate a blank containing the reagents and a volume of distilled water equal to that of the sample.

Calculation

$$\text{COD as mg O}_2\text{/L} = \frac{(A - B) \times M \times 8000}{\text{mL sample}}$$

where:

A = mL FAS used for blank,

B = mL FAS used for sample,

M = molarity of FAS, and

8000 = mill equivalent weight of oxygen \times 1000 mL/L.

Preferably analyse samples in duplicate because of small sample size. Samples that are inhomogeneous may require multiple determinations for accurate analysis. Results should agree within $\pm 5\%$ of their average unless the condition of the sample dictates otherwise.

2. Determination of Total Suspended Solids (TSS) Dried at 103–105°C using standard operating procedure

a. Preparation of glass-fibre filter disk: Insert disk with wrinkled side up in filtration apparatus. Apply vacuum and wash disk with three successive 20-ml portions of reagent-grade water. Continue suction to remove all traces of water, turn vacuum off, and discard washings. Remove filter from filtration apparatus and transfer to an inert aluminium weighing dish. If a Gooch crucible is used, remove crucible and filter combination. Dry in an oven at 103 to 105°C for 1h. If volatile solids are to be measured, ignite at 550°C for 15 min in a muffle furnace. Cool in desiccator to balance temperature and weigh. Repeat cycle of drying or igniting, cooling, desiccating, and weighing until a constant weight is obtained or until weight change is less than 4% of the previous weighing or 0.5 mg, whichever is less. Store in desiccators until needed.

b. Selection of filters and sample sizes: Choose sample volume to yield between 2.5 and 200 mg dried residue. If volume filtered fails to meet minimum yield, increase sample volume up to 1l. If complete filtration takes more than 10 min, increase filter diameter or decrease sample volume.

c. Sample analysis: Assemble filtering apparatus and filter and begin suction. Wet filter with a small volume of reagent-grade water to seat it. Stir sample with a magnetic stirrer at a speed to shear larger particles, if practical, to obtain a more uniform (preferably homogeneous) particle size. Centrifugal force may separate particles by size and density, resulting in poor precision when point of sample withdrawal is varied. While stirring, pipet a measured volume onto the seated glass-fibre filter. For homogeneous samples, pipet from the approximate midpoint of container but not in vortex. Choose a point both middepth and midway between wall and vortex.

Wash filter with three successive 10-mL volumes of reagent-grade water, allowing complete drainage between washings, and continue suction for about 3 min after filtration is complete.

Samples with high dissolved solids may require additional washings. Carefully remove filter from filtration apparatus and transfer to an aluminium weighing dish as a support. Alternatively, remove the crucible and filter combination from the crucible adapter if a Gooch crucible is used. Dry for at least 1 h at 103 to 105°C in an oven, cool in a desiccator to balance temperature, and weigh. Repeat the cycle of drying, cooling, desiccating, and weighing until a constant weight is obtained or until the weight change is less than 4% of the previous weight or 0.5 mg, whichever is less. Analyse at least 10% of all samples in duplicate. Duplicate determinations should agree within 5% of their average weight.

Calculation

$$\text{mg total suspended solids/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

where:

A = weight of filter + dried residue, mg, and

B = weight of filter, mg.

3. Determination of Nitrate/Nitrite (Lachat Method)

Soak digestion tubes in 1:1 HCl for 1 hour, rinse thoroughly with reagent water and allow drying completely before use. Using an automatic pipette with disposable tip, withdraw a 9.5 ml aliquot of sample. Discard this first portion. Withdraw another 9.5 ml aliquot and transfer to a digestion tube. Add 0.5 ml of digestion solution. Cap the tube tightly and place in metal digestion rack. Prepare all samples, calibration standards, blanks, and control standards in the same manner. Place the rack of tubes in an autoclave at 121°C for 30 minutes. Allow the samples to cool to

room temperature before analysis. Redigest any tubes that gain or lose volume. Allow at least 20 minutes for the heating block to warm up to 37°C. Follow the Lachat Procedural SOP (Typical Daily Operation Section) for the remainder of the analysis. At the end of a run, place all lines into the NaOH-EDTA solution (6.11). Pump this solution for approximately 5 minutes. Rinse lines with reagent water for another 5 - 10 minutes.

Calculations

The computer yields results directly in µg P/L.

4. Determination of Chloride using standard operating procedure

a. Sample preparation: Use a 100-ml sample or a suitable portion diluted to 100 ml. If the sample is highly coloured, add 3 ml Al (OH)₃ suspension, mix, let settle, and filter. If sulphide, sulphite, or thiosulfate is present, add 1 mL H₂O₂ and stir for 1 min.

b. Titration: Directly titrate samples in the pH range 7 to 10. Adjust sample pH to 7 to 10 with H₂SO₄ or NaOH if it is not in this range. For adjustment, preferably use a pH meter with a non-chloride-type reference electrode. (If only a chloride-type electrode is available, determine amount of acid or alkali needed for adjustment and discard this sample portion. Treat a separate portion with required acid or alkali and continue analysis.) Add 1.0 mL K₂CrO₄ indicator solution. Titrate with standard AgNO₃ titrant to a pinkish yellow end point. Be consistent in end-point recognition. Standardize AgNO₃ titrant and establish reagent blank value by the titration method outlined above. A blank of 0.2 to 0.3 mL is usual.

Calculation

$$\text{mg Cl}^-/\text{L} = \frac{(A - B) \times N \times 35\,450}{\text{mL sample}}$$

where:

A = mL titration for sample,

B = mL titration for blank, and

N = normality of AgNO_3 .

$$\text{mg NaCl/L} = (\text{mg Cl}^-/\text{L}) \times 1.65$$

5. Determination of colour for water using standard operating procedure

Quantitative determination of the water colour (called water colour index) is carried out by colorimetric analysis, i.e. cobalt solutions (potassium chloroplatinate K_2PtCl_6 mixed with cobalt chloride $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$). The primary reference solution is prepared as a mixture of 1.264 g of platinum salt with 1.009g of crystalline cobalt chloride hexahydrate. These amounts of salts are dissolved in 100ml of distilled water; 100 ml of hydrochloric acid with specific gravity 1.19 g cm^{-3} is added to this solution, and its volume is adjusted to 1.01 with distilled water. The colour index of the obtained solution is taken as 500°, because it contains 500 g of pure platinum per 10^6 ml of water. Standard solutions are prepared from various amount of the primary solution:

- No. 1 – colour index 0° (distilled water);
- No. 2 - 10° (4ml of primary solution are diluted with distilled water to a volume of 200 ml);

- No. 3 - 20° (8ml of primary solution are diluted with distilled water to a volume of 200 ml);
- No. 4 - 30° (12ml of primary solution are diluted with distilled water to a volume of 200 ml);
- No. 5 - 40° (16ml of primary solution are diluted with distilled water to a volume of 200 ml);
- No. 9 - 80° (32ml of primary solution are diluted with distilled water to a volume of 200 ml);

The water under investigation is compared with the reference solutions using a set of similar cylinders made of colourless glass, and so its colour index is determined. The colour index of the natural water depends on the presence of humic acids in the soil, on biological processes (water florescence), and on pollutants of various origin. This latter factor is decisive for waste water.

6. Determination of calcium using calculation method

Calcium may be estimated as the difference between hardness and

$$\text{mg Mg/l} = [\text{total hardness (as mg CaCO}_3\text{/l)} - \text{calcium hardness (as mg CaCO}_3\text{/L)}] \times 0.243$$

7. Determination of magnesium using standard operating procedure

a. Preparation of evaporating dish: If volatile solids are to be measured ignite clean evaporating dish at 550°C for 1h in a muffle furnace. If only total solids are to be measured, heat clean dish to 103 to 105°C for 1h. Store and cool dish in desiccators until needed. Weigh immediately before use.

b. Sample analysis: Choose a sample volume that will yield a residue between 2.5 and 200 mg. Pipet a measured volume of well-mixed sample, during mixing, to a preweighed dish. For homogeneous samples, pipet from the approximate midpoint of the container but not in the vortex. Choose a point both middepth and midway between wall and vortex. Evaporate to dryness on a steam bath or in a drying oven. Stir sample with a magnetic stirrer during transfer. If necessary, add successive sample portions to the same dish after evaporation. When evaporating in a drying oven, lower temperature to approximately 2°C below boiling to prevent splattering. Dry evaporated sample for at least 1h in an oven at 103 to 105°C, cool dish in desiccators to balance temperature, and weigh. Repeat cycle of drying, cooling, desiccating, and weighing until a constant weight is obtained, or until weight change is less than 4% of previous weight or 0.5 mg, whichever is less. When weighing dried sample, be alert to change in weight due to air exposure and/or sample degradation. Analyse at least 10% of all samples in duplicate. Duplicate determinations should agree within 5% of their average weight

Calculation

$$\text{mg total solids/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

where:

A = weight of dried residue + dish, mg, and

B = weight of dish, mg.

8. Determination of fluoride using SPADNS method

a. Preparation of standard curve: Prepare fluoride standards in the range of 0 to 1.40 mg F-/L by diluting appropriate quantities of standard fluoride solution to 50 ml with distilled water. Pipet 5.00 ml each of SPADNS solution and zirconyl-acid reagent, or 10.00 ml mixed acid-zirconyl-SPADNS reagent, to each standard and mix well. Avoid contamination. Set photometer to zero absorbance with the reference solution and obtain absorbance readings of standards. Plot a curve of the milligrams fluoride-absorbance relationship. Prepare a new standard curve whenever a fresh reagent is made or a different standard temperature is desired. As an alternative to using a reference, set photometer at some convenient point (0.300 or 0.500 absorbance) with the prepared 0 mg F-/L standard.

b. Sample pre-treatment: If the sample contains residual chlorine, remove it by adding 1 drop (0.05 mL) NaAsO₂ solution/ 0.1 mg residual chlorine and mix. (Sodium arsenite concentrations of 1300 mg/L produce an error of 0.1 mg/L at 1.0 mg F-/L.)

c. Colour development: Use a 50.0-ml sample or a portion diluted to 50 ml with distilled water. Adjust sample temperature to that used for the standard curve. Add 5.00 ml each of SPADNS solution and zirconyl-acid reagent, or 10.00 ml acid-zirconyl-SPADNS reagent; mix well and read absorbance, first setting the reference point of the photometer as above. If the absorbance falls beyond the range of the standard curve, repeat using a diluted sample.

Calculation

where:

A = $\mu\text{g F-}$ determined from plotted curve,

B = final volume of diluted sample, ml, and

C = volume of diluted sample used for colour development, ml.

When the prepared 0 mg F⁻/L standard is used to set the photometer, alternatively calculate fluoride concentration as follows:

$$\text{mg F}^{-}/\text{L} = \frac{A_0 - A_x}{A_0 - A_1}$$

where:

A₀ = absorbance of the prepared 0 mg F⁻/L standard,

A₁ = absorbance of a prepared 1.0 mg F⁻/L standard, and

A_x = absorbance of the prepared sample.

9. Determination of pH using calibration method

a. Calibration: To calibrate, rinse the probe tip with de-ionized water and blot dry with Kimwipes⁷, then place the tip of the electrode into the pH 7.0 buffer solution and press “Cal” one time so that “pH 7” and “Cal 1” appear. The pH meter will automatically read the endpoint when the reading is stable. The appropriate buffer symbol will appear on the display. Record the pH value on the pH Meter Calibration Check Record Form. Rinse the tip of the electrode with de-ionized water and blot dry with Kimwipes⁷. Place the tip of the electrode in the second calibration buffer. If pH buffer 4.0 is used, press “Cal” one time so that “pH 4” and “Cal 3” appear. If pH buffer 10.0 is used, press “Cal” two times so that “pH 10” and “Cal 3” appear. The pH meter will automatically read the endpoint when the reading is stable and the appropriate buffer symbol will appear on the display. The display will show the electrode slope value. Record the pH value and slope on the pH Meter

Calibration Check Record Form (see 16.0). If the slope is less than 95% or greater than 105%, refer to the troubleshooting section of the Corning pH meter 430 instruction manual.

Rinse the electrode with de-ionized water and blot dry with

Kimwipes⁷. Confirm the calibration by reading the pH of a standard pH 7.0 buffer a second time

b. measuring sample pH: After calibrating your meter with the buffers, rinse the electrode(s) and glassware with distilled or deionised water. Carefully measure 100 ml of your sample and place in a 150 ml beaker for the pH and alkalinity part. Place the rinsed electrode in the test sample. We strongly encourage letting all samples come to room temperature in the tightly capped bottle before analysing. If you are conducting other analyses with the sample water, keep in mind that pH should be analysed within 5 minutes of uncapping the sample bottle. The sample should be stirred very gently, preferably with a magnetic stirrer. It may take up to 3 minutes for the reading to become stable. When stable, but not in excess of 5 minutes, record the sample pH to the nearest 0.01 pH unit

10. Determination of sulphate using turbidimetric method

a. Formation of barium sulphate turbidity: Measure 100 ml sample, or a suitable portion made up to 100 ml, into a 250-mL Erlenmeyer flask. Add 20 ml buffer solution and mix in stirring apparatus. While stirring, add a spoonful of BaCl₂ crystals and begin timing immediately. Stir for 60 ± 2 s at constant speed.

b. Measurement of barium sulphate turbidity: After stirring period has ended, pour solution into absorption cell of photometer and measure turbidity at 5 ± 0.5 min.

c. Preparation of calibration curve: Estimate SO_4^{2-} concentration in sample by comparing turbidity reading with a calibration curve prepared by carrying SO_4^{2-} standards through the entire procedure. Space standards at 5-mg/L increments in the 0- to 40-mg/L SO_4^{2-} range.

Above 40 mg/l accuracy decreases and BaSO_4 suspensions lose stability. Check reliability of calibration curve by running a standard with every three or four samples.

d. Correction for sample colour and turbidity: Correct for sample colour and turbidity by running blanks to which BaCl_2 is not added

$$\text{mg SO}_4^{2-}/\text{L} = \frac{\text{mg SO}_4^{2-} \times 1000}{\text{mL sample}}$$

Calculation

If buffer solution A was used, determine SO_4^{2-} concentration directly from the calibration curve after subtracting sample absorbance before adding BaCl_2 . If buffer solution B was used subtract SO_4^{2-} concentration of blank from apparent SO_4^{2-} concentration as determined above; because the calibration curve is not a straight line, this is not equivalent to subtracting blank absorbance from sample absorbance.

11. Determination of total dissolved solids (TDS) Dried at 180°C with standard operating procedure

a. Preparation of glass-fibre filter disk: Insert disk with wrinkled side up into filtration apparatus. Apply vacuum and wash disk with three successive 20-mL volumes of reagent-grade water. Continue suction to remove all traces of water. Discard washings.

b. Preparation of evaporating dish: If volatile solids are to be measured, ignite cleaned evaporating dish at 550°C for 1 h in a muffle furnace. If only total dissolved solids are to be measured, heat clean dish to $180 \pm 2^\circ\text{C}$ for 1 h in an oven. Store in desiccators until needed.

Weigh immediately before use.

c. Selection of filters and sample sizes: Choose sample volume to yield between 2.5 and 200 mg dried residue. If more than 10 min are required to complete filtration, increase filter size or decrease sample volume.

d. Sample analysis: Stir sample with a magnetic stirrer and pipet a measured volume onto a glass-fibre filter with applied vacuum. Wash with three successive 10-mL volumes of reagent-grade water, allowing complete drainage between washings, and continue suction for about 3 min after filtration is complete. Transfer total filtrate (with washings) to a weighed evaporating dish and evaporate to dryness on a steam bath or in a drying oven. If necessary, add successive portions to the same dish after evaporation. Dry evaporated sample for at least 1 h in an oven at $180 \pm 2^\circ\text{C}$, cool in a desiccators to balance temperature, and weigh. Repeat drying cycle of drying, cooling, desiccating, and weighing until a constant weight is obtained or until weight change is less than 4% of previous weight or 0.5 mg, whichever is less. Analyse at least 10% of all samples in duplicate. Duplicate determinations should agree within 5% of their average weight.

Calculation

where:

$$\text{mg total suspended solids/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

A = weight of dried residue + dish, mg, and

B = weight of dish, mg.

12. Determination of hardness using EDTA titrimetric method

a. Pre-treatment of polluted water and wastewater samples: Use nitric acid-sulphuric acid or nitric acid-perchloric acid digestion.

b. Titration of sample: Select a sample volume that requires less than 15 ml EDTA titrant and complete titration within 5 min, measured from time of buffer addition.

Dilute 25.0 mL sample to about 50 mL with distilled water in a porcelain casserole or other suitable vessel. Add 1 to 2 mL buffer solution. Usually 1 mL will be sufficient to give a pH of 10.0 to 10.1. The absence of a sharp end-point colour change in the titration usually means that an inhibitor must be added at this point or that the indicator has deteriorated. Add 1 to 2 drops indicator solution or an appropriate amount of dry-powder indicator formulation. Add standard EDTA titrant slowly, with continuous stirring, until the last reddish tinge disappears. Add the last few drops at 3- to 5-s intervals. At the end point the solution normally is blue. Daylight or a daylight fluorescent lamp is recommended highly because ordinary incandescent lights tend to produce a reddish tinge in the blue at the end point. If sufficient sample is available and interference is absent, improve accuracy by increasing sample size.

c. Low-hardness sample: For ion-exchanger effluent or other softened water and for natural waters of low hardness (less than 5 mg/L), take a larger sample, 100 to 1000 ml, for titration and add proportionately larger amounts of buffer, inhibitor, and indicator. Add standard EDTA titrant

slowly from a microburet and run a blank, using redistilled, distilled, or deionised water of the same volume as the sample, to which identical amounts of buffer, inhibitor, and indicator have been added. Subtract volume of EDTA used for blank from volume of EDTA used for sample.

Calculation

where:

$$\text{Hardness (EDTA) as mg CaCO}_3/\text{L} = \frac{A \times B \times 1000}{\text{mL sample}}$$

A = mL titration for sample and

B = mg CaCO₃ equivalent to 1.00 mL EDTA titrant.

13. Determination of turbidity using Nephelometric method

General measurement techniques: Proper measurement techniques are important in minimizing the effects of instrument variables as well as stray light and air bubbles. Regardless of the instrument used, the measurement will be more accurate, precise, and repeatable if close attention is paid to proper measurement techniques. Measure turbidity immediately to prevent temperature changes and particle flocculation and sedimentation from changing sample characteristics. If flocculation is apparent, break up aggregates by agitation. Avoid dilution whenever possible. Particles suspended in the original sample may dissolve or otherwise change characteristics when the temperature changes or when the sample is diluted.

Remove air or other entrained gases in the sample before measurement. Preferably degas even if no bubbles are visible. Degas by applying a partial vacuum, adding a non foaming-type surfactant, using an ultrasonic bath, or applying heat. In some cases, two or more of these techniques may be combined for more effective bubble removal. For example, it may be

necessary to combine addition of a surfactant with use of an ultrasonic bath for some severe conditions. Any of these techniques, if misapplied, can alter sample turbidity; *use with care*. If degassing cannot be applied, bubble formation will be minimized if the samples are maintained at the temperature and pressure of the water before sampling. Do not remove air bubbles by letting sample stand for a period of time because during standing, turbidity-causing particulates may settle and sample temperature may change. Both of these conditions alter sample turbidity, resulting in a non-representative measurement. Condensation may occur on the outside surface of a sample cell when a cold sample is being measured in a warm, humid environment. This interferes with turbidity measurement. Remove all moisture from the outside of the sample cell before placing the cell in the instrument. If fogging recurs, let sample warm slightly by letting it stand at room temperature or by partially immersing it in a warm water bath for a short time. Make sure samples are again well mixed.

b. Nephelometer calibration: Follow the manufacturer's operating instructions. Run at least one standard in each instrument range to be used. Make certain the nephelometer gives stable readings in all sensitivity ranges used.

c. Measurement of turbidity: Gently agitate sample. Wait until air bubbles disappear and pour sample into cell. When possible, pour well-mixed sample into cell and immerse it in an ultrasonic bath for 1 to 2 seconds or apply vacuum degassing, causing complete bubble release. Read turbidity directly from instrument display.

d. Calibration of continuous turbidity monitors: Calibrate continuous turbidity monitors for low turbidities by determining turbidity of the water flowing out of them, using a laboratory-model nephelometer, or calibrate the instruments according to manufacturer's instructions with formalin primary standard or appropriate secondary standard.

14. Determination of total coliform using standard operating procedure

Add absorbent pads to sterile Petri dishes for the number of samples to be processed. Sterile pads may be placed in the Petri dishes with sterile forceps or with an automatic dispenser as shown in. Soak the pads with nutrient medium. Nutrient medium may be dispensed with a sterile pipette or by carefully pouring from an ampoule or bottle. In all cases, a slight excess of medium should be added (e.g. about 2.5 ml). Immediately before processing a sample, drain off most of the excess medium, but always ensure that a slight excess remains to prevent the pad drying during incubation. Note: Absorbent pads soaked in liquid medium may be replaced by medium solidified by agar. In this case, Petri dishes should be prepared in advance and stored in a refrigerator. Sterilize the tips of the blunt-ended forceps in a flame and allow them to cool. Carefully remove a sterile membrane filter from its package, holding it only by its edge. Place the membrane filter in the filter apparatus and clamp it in place. If the apparatus has been disinfected by boiling, ensure that it has cooled down before inserting the membrane filter. Mix the sample by inverting its container several times. Pour or pipette the desired volume of sample into the filter funnel. This volume should normally be chosen in the light of previous experience. If the volume to be filtered is less than 10 ml, it should be made up to at least 10 ml with sterile diluents so that the sample will be distributed evenly across the filter during filtration. Alternatively, the sample may be diluted as suggested previously. Apply a vacuum to the suction flask and draw the sample through the filter; disconnect vacuum. Dismantle the filtration apparatus and remove the membrane filter using the sterile forceps, taking care to touch only the edge of the filter. Remove the lid of a previously prepared Petri dish and place the membrane, grid side uppermost, onto the pad (or agar). Lower the membrane, starting at one edge in order to avoid trapping air bubbles. Replace the lid of the Petri dish and mark it with the sample number

or other identification. The sample volume should also be recorded. Use a wax pencil or waterproof pen when writing on Petri dishes. If membranes are going to be incubated at 44 or 44.5 °C, the bacteria on them may first require time to acclimatize to the nutrient medium. After processing samples from areas of temperate climate, leave each Petri dish at environmental temperature for 2 hours before placing it in the incubator. Samples from areas of tropical climate may be incubated immediately. Maintain the Petri dish in a humid atmosphere (e.g. in a plastic bag or in a small container with a moist pad in the base) and incubate it either in an incubator or in a weighed canister in a water bath. This ensures that the pad does not dry out during the incubation period. Incubate for 18-24 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms and 18-24 hours at 44 ± 0.25 °C or 44.5 ± 0.25 °C for thermos tolerant coliforms. Once a yellow colour extending on to the membrane remove the membrane. After incubation, count the colonies. Express the results as number of colonies per 100 ml of sample. Where smaller volumes have been used, results are calculated from the following formula:

$$\text{No. of colonies per 100 ml} = [(\text{No. of colonies}) / (\text{volume filtered})] \times 100$$

The colonies counted at this stage are presumed to be coliform bacteria (presumptive results).

Appendix 5: Ethical approval for research study on pigs



21 April 2014

Reference: 083/14/Animal

Miss SG Mabuza
Animal Science
School of Agricultural, Earth &
Environmental Sciences
University of KwaZulu-Natal
PIETERMARITZBURG Campus

Dear Miss Mabuza

Ethical Approval of Research Projects on Animals

I have pleasure in informing you that the Animal Research Ethics Committee has granted ethical approval for 2014 on the following project:

"Effect of grey water from the dairy industry on pig performance."

Yours sincerely

Professor Theresa HT Coetzer
Chairperson: Animal Ethics Sub-committee

Cc Registrar – Mr C Baloyi
Research Office – Dr N Singh
Supervisor – Prof. M Chimonyo
Head of School – Prof. A Modi
SAEES – Mrs M Manjoo

Animal Ethics Committee Professor Theresa HT Coetzer (Chair)

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