Natsurv 8:

Water and Wastewater Management in the Laundry Industry

(Edition 2)

CD Swartz, G Swanepoel, PJ Welz,
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NATSURV 8
Water and Wastewater Management in the Laundry Industry
(Edition 2)

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND

In the 1980s the Water Research Commission and Department of Water Affairs embarked on a series of national surveys for 16 industries. These reports were referred to as NATSURV documents, focussing on the water and wastewater management of these industries. The NATSURV reports of the different industries have been well used by the sector. However, South Africa and its industrial sectors have either grown or in some cases shrunk considerably since the 1980s. The landscape has changed, and new technologies and systems have been adopted by some of the industries. Thus, some of the information contained in the national surveys can be considered out of date. Through the UN CEO Water Mandate, water stewardship discussions, water allocation and equity dialogues, we are also seeing a growing awareness around water use, water security and waste production. It is therefore considered an opportune time to review the water and wastewater management practices of the different industrial sectors.

The current project is concerned with the water and wastewater management of the laundry industry. The first NATSURV document of this industry presented data collected from 16 laundries, excluding laundromats. In this edition, data from laundromats, as well as data previously collected from domestic/household laundries are included. However, as was the case with the first edition, no active surveying of the local household laundry sector was performed as it is not an industrial entity.

AIMS

The main aims of the project were to: provide a detailed overview of the laundry industry in South Africa, and its changes since 1980; determine the water consumption and specific water consumption in the industry; determine wastewater generation and typical pollutant loads; and provide recommendations on best practices for the laundry industry.

ETHODOLOGY

To obtain information on the current status of the laundry industry in South Africa and specifically its water and wastewater management practices, the approach was to perform a thorough search of the internet and business directories, and compile a database of laundries on a provincial basis. Laundries were then contacted by telephone and information gathered with the use of questionnaires that were developed for this purpose. Large laundries were subsequently identified in the main metropolitan areas of the country, and visits arranged to the laundries for personal interviews and surveys of the washing facilities (where this was allowed), as described below.

The first step entailed determining the commercial laundries operating in the country. The electronic databases of “SA Yellow Pages” (www.sayellow.com) and “Brabys Online Business Directory” (www.brabys.co.za), that included laundromats, were consulted. This information was used to compile a database of all the laundries in the country. Two further databases were also created: the first included prominent companies and institutions that supply chemicals or equipment to laundries, while the second consisted of major clients of the commercial laundry industry. These databases served as secondary sources of information, and to enable a more informed choice about which commercial laundries to visit.

Telephonic surveys were then carried out on a large number of these laundries (excluding laundromats and those medium to large laundries which were identified for site visits). Telephonic surveys were also conducted with the laundry chemicals and equipment suppliers, as well as with the major laundry clients, e.g. hospitals, school and university residences, and the hospitality industry.

Based on the information obtained during the telephonic surveys, laundries representative of the small, medium and large laundry sectors were selected for site visits. After pre-selection, the final selection was based on industry co-operation. The chemical suppliers, a laundry equipment supplier and several large laundry clients provided information about which the largest and most active role-players are in the laundry industry are. These are all located in the Western Cape, Kwazulu-Natal and Gauteng. Visits were initially performed in the Western Cape, where the research team is based. These visits served as springboard for additional site visits to other centres in South Africa.

BEST PRACTICES: WATER USE AND MANAGEMENT

The application of water-conservation techniques should enable commercial laundries to have specific water intakes (SWIs) of 12-15 L/kg laundry for washing extractors (WEs) and 1.5-4.5 L/kg laundry for continuous batch washers (CBWs) (Brown, 2009). Water consumption must be accurately monitored and ultimately compared with theoretical, programmed water use. When the comparison reveals that more water is used than required, it will then be possible to start identifying causes. Options for reducing the total water usage of a commercial laundry include the following (Seneviratne, 2007):

- Repair leaking drain valves and hoses – a 3% reduction in water usage is realisable.
- Excessive steam generation must be inspected.
- Computerised programming relating to water usage during laundering process must be optimised (*Training Modules on the Sustainability of Industrial Laundering Processes, n.d.*).
- Chemical dosage must be monitored – Too much relates to more rinsing water required, whilst too little leads to insufficient results which require repeated washing.
- Whilst incorporated in most CBWs, the re-use of rinsing water for pre- and main wash water should be considered in WEs, with up to 30% savings on laundering water possible.
- Washing machines should not be over-loaded, since insufficient results will require repeated washing.
- Washing machines should not be under-loaded, since this can result in wastage of water.
- The residual water extracted by mechanical pressing can be collected and re-used in the washing stage.
- A cascade system – using laundering water from high-on-quality demand textiles (e.g. hotel linen) on low-on-quality demand textiles (e.g. garage work-wear) – can reduce total water intake (*Training Modules on the Sustainability of Industrial Laundering Processes, n.d.*).
- The use of ozone for disinfection can reduce the amount of chemicals and rinse cycles used, which can lead to total laundering water savings of up to 20%.
- Water efficient installations in amenities blocks (*Training Modules on the Sustainability of Industrial Laundering Processes, n.d.*).
- When buying washing machines, WEs and CBWs with internal recycling measures should be considered (*Training Modules on the Sustainability of Industrial Laundering Processes, n.d.*).

BEST PRACTICES: WASTEWATER GENERATION AND MANAGEMENT

It is recommended that more economic and simple wastewater treatment processes should be reviewed and implemented first before proceeding with more sophisticated options. Emphasis is placed on the control of pH and the removal of solids.

The control of pH is essential since municipalities generally limit the wastewater they receive to a pH range between 5 and 9. Failing to adhere to this pH range would incur an avoidable extra charge to the laundry. The highly alkaline wastewater generated by commercial laundries can be treated with an acidifying chemical. This dosage option is only advisable if its cost does not exceed the municipal discharge penalties.

The only solids in laundry wastewater are colloidals and/or tiny particles suspended in water. Colloidals will not settle out unaided so coagulation and flocculation chemicals (water- soluble electrolytes and polymers) can be added to assist in the sedimentation process. For a relatively small capital outlay for a settling tank and some chemical dosing equipment, a considerable improvement in the quality of the wastewater can be expected, with concurrent savings in municipal wastewater treatment charges.

For further treatment of laundry wastewaters, e.g. for reuse of rinse water as well as wash water, more sophisticated treatments may be necessary. These processes are all capital intensive and would only be worth considering as a second stage after the implementation of simple wastewater treatment and management measures. The following options are mentioned:

- Cross-flow microfiltration: A pressure-driven filtration process for the removal of suspended and colloidal particles.
- Dissolved air flotation (DAF): Operates by dissolving air under pressure in the wastewater and then allowing this wastewater to suddenly return to atmospheric pressure. The dissolved air forms tiny bubbles which adhere to any solid material in the wastewater and floats them to the surface where they can be removed easily.

- Ultrafiltration (UF): Membranes are used to mechanically separate suspended solids (SS) from a liquid solution. The UF process can be used to separate out large organic molecules from solutions. DAF and/or UF has been found to completely remove the faecal indicator organisms, *Escherischia coli* from laundry wastewater, but as a safety measure, the treated wastewater could also be disinfected prior to reuse (e.g. by chlorination or ozonation).

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ACRONYMS AND ABBREVIATIONS

BOD	Biological oxygen demand
CBW	Continuous Batch Washer, sometimes referred to as tunnel washers
COD	Chemical oxygen demand
EC	Electrical conductivity
FOG	Fat, oil and grease
OPL	On-premise laundry
PO_4-P	Phosphate (as phosphorous)
RO	Reverse osmosis
SPL	Specific pollutant load
SS	Suspended solids
SWI	Specific water intake
TDS	Total dissolved solids
UF	Ultrafiltration
WE	Washer-extractor

CHAPTER 1: INTRODUCTION

1.1 INDUSTRY OVERVIEW

In South Africa 360 million tons of textiles is processed every year by the laundry industry. This figure is bound to increase, with the growth rate of the industry currently at 6% (Bidvest Laundry Group. n.d.). In 1989, it was estimated that 3 Mm^3 of water was used and 2.85 Mm^3 wastewater was discharged by the laundry industry in South Africa (Steffen, Robertson and Kirsten, 1989). More recently, it was determined that the laundry industry contributed 0.07% (0.2340 Mm^3) and 0.32% (0.2186 Mm^3) towards the annual industrial water consumption and effluent production, respectively (Cloete *et al*., 2010). Most laundry effluents are discharged to municipal sewerage systems and are treated at local wastewater treatment facilities. There are, however, institutions such as hotels which are not located near cities, and they reportedly choose to discharge their laundry wastewater into the natural environment (Cloete *et al*., 2010).

The laundry industry in South Africa is discussed further in Chapter 2.

1.2 PROJECT OBJECTIVES AND SCOPE

The specific aims of the project were to:

- Provide a detailed overview of the laundry industry in South Africa, its changes since 1980 and its projected change(s). It is important that representative samples of the respective industries are used as case studies.
- Critically evaluate and document the "generic" industrial processes of laundry industry in terms of current practice, best practice and cleaner production.
- Determine the water consumption and specific water consumption (local and global indicators, targets; benchmarks, diurnal trends) and recommend targets for use, reuse, recycling and technology adoption.
- Determine wastewater generation, and typical pollutant loads and best practice technology adoption.
- Critically evaluate the specific industry water (including wastewater) management processes adopted and provide appropriate recommendations.
- Provide recommendations on the best practice for this industry.

1.3 APPROACH AND METHODOLOGY

To obtain information on the current status of the laundry industry in South Africa and specifically its water and wastewater management practices, the approach was to do a thorough search of the internet and business directories, and compiling a database of laundries on a provincial basis. Laundries were then contacted by telephone and information gathered with the use of questionnaires that were developed for this purpose. Large laundries were subsequently identified in the main metropolitan areas of the country, and visits arranged to the laundries for personal interviews and surveys of the washing facilities (where this was allowed), as described below.

1.3.1 Surveys conducted

It was established that since the literature review did not reveal sufficient information regarding the water and wastewater management practices of the South African laundry industry, surveys would need to be conducted to attain this information. The first step entailed determining the commercial laundries operating in the country. The "SA Yellow Pages" (www.sayellow.com) and "Brabys Online Business Directory" (www.brabys.co.za) were used to conduct an internet search of laundry businesses in South Africa. Laundromats were automatically included when searching for commercial laundries. A database was created of all the laundries in the country obtained from this internet search to serve as basis for obtaining further information on laundry operations. Two further databases were created, which served as a further source for the selection of currently operating laundries to visit. The first included prominent companies and institutions that supply chemicals or equipment to laundries, while the second consists of major clients of the commercial laundry industry.

Telephonic surveys were then carried out on a large number of these laundries (excluding laundromats and those medium to large laundries which were identified for site visits). Telephonic surveys were also conducted with the laundry chemicals and equipment suppliers, as well as with the major laundry clients, e.g. hospitals, school and university residences, and the hospitality industry.

1.3.2 Laundry site visits

Based on the information obtained during the telephonic surveys that were carried out, laundries representative of the small, medium and large laundry sectors were selected for site visits. The selection was subject to whether these companies wished to cooperate with this project. The chemical suppliers, a laundry equipment supplier and several large institutions potentially associated with requiring external laundering services (clients of laundries) provided information on which the largest and most active role-players are in the laundry industry are. These companies and institutions are all located in the Western Cape, Kwazulu-Natal and Gauteng. Identifying laundries in the Western Cape to visit, besides logistical reasons, served as springboard for other site visits in the rest of South Africa.

CHAPTER 2: LAUNDERING PROCESS OVERVIEW

2.1 PROCESS OVERVIEW

Commercial, institutional and industrial laundries are designed to handle a broad range of items in large quantities, which can originate from a variety of industries, including mines, hotels, restaurants, catering firms, hospitals, prisons, etc. These laundries serve to provide a constant flow of clean textiles to clients. This entails maximum dirt and stain removal, enhancing the smell, look and feel of the textile and ensuring that the relevant hygienic standards are met.

The laundering process has since the publication of the first edition of NATSURV 8 been optimised, but the general principles by which laundry industries operate have still remained the same. A flow diagram of the laundry processes is provided in Figure 2.1:

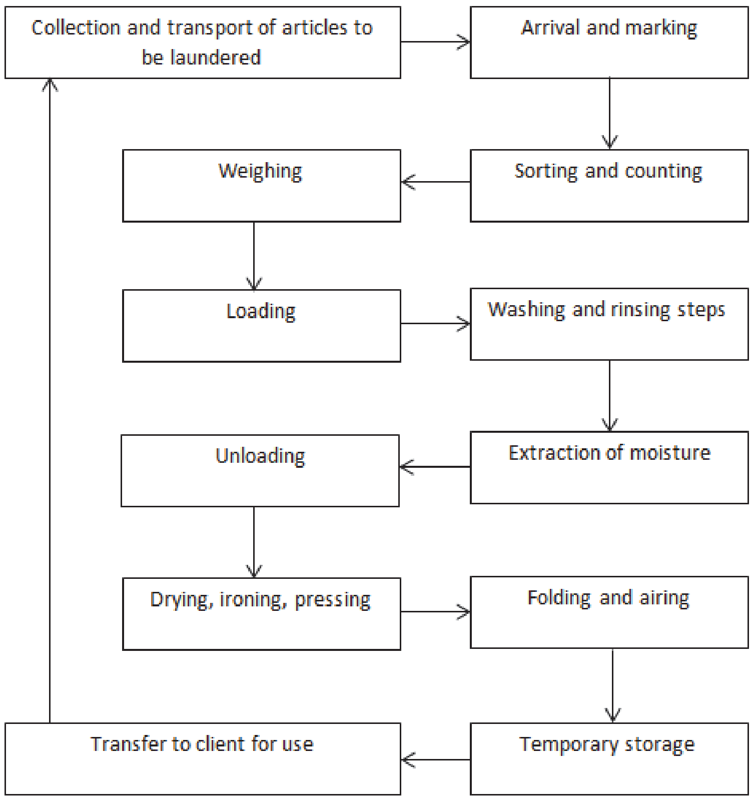


Figure 2.1: Work-flow of the laundry industry (adapted from Laundry Process Layout).

In the laundry industry, up to four washing and four rinsing steps can be used, but a two-wash and two-rinsing process is deemed adequate for most applications. The wash stage is concerned with removing dirt from textiles through agitation in an aqueous medium containing a detergent. The suspension that is formed is stabilised to prevent re-deposition of dirt on the cloth. The rinsing stage is subsequently performed to remove the stabilised suspension of dirt from coming into contact with the textile being washed. The rinsing stage also uses considerably greater amounts of water when compared to the washing stage (Steffen, Robertson and Kirsten, 1989). The main steps in the laundering process are shown in Figure 2.2.

Raw materials (textile articles)

Different types of textile require different washing programs. It is therefore essential to sort these articles. These items must also be weighed and loaded according to each machine's loading capacity.

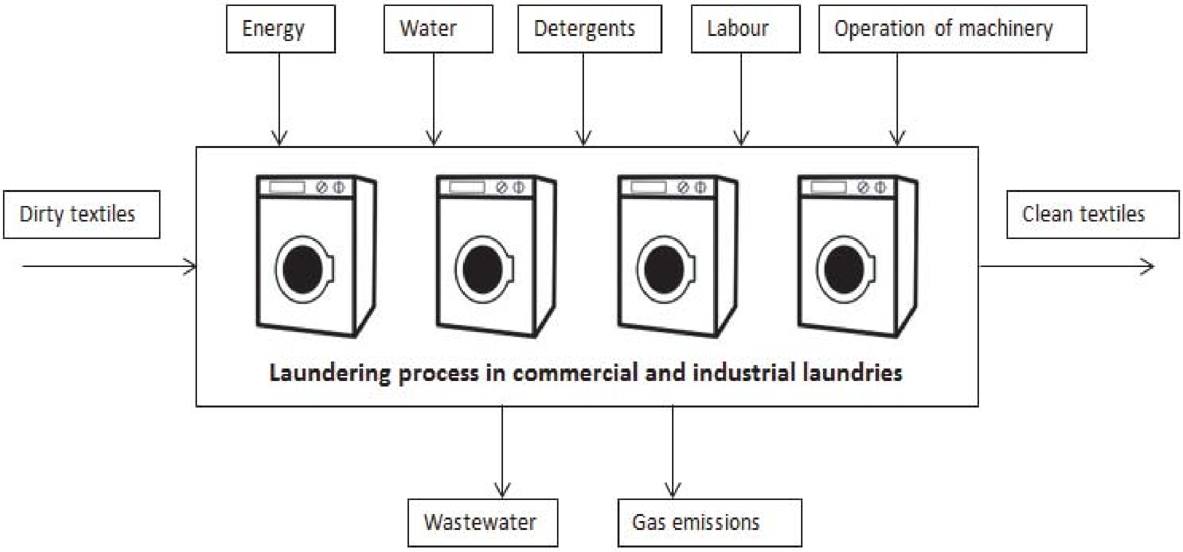


Figure 2.2: Main elements associated with the laundering process (adapted from Máša *et al.,* 2013)

Resources/consumables

The resources/consumables include energy, water, chemicals, labour and manpower for operation of the machinery.

a. Energy

The amount of energy required for operating a laundry constitutes the second highest cost, after labour (Seneviratne, 2007). Energy is required to operate the machinery, which can include washing machines, conveyor belts, boilers, dryers and ironers. Smaller laundries usually heat their water by electrical means, whilst large laundries prefer direct steam injection (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

b. Water

Water is the universal solvent for water-soluble dirt particles and chemical detergents. Besides being the medium in which chemicals react and dirt-particles are displaced, it also facilitates mechanical and thermal energy transfer to textiles (Raghava *et al*., 2003). The quality and quantity of water that laundries use are also essential towards the laundering process. The laundry industry can receive water through its local municipal water supply, or, less conveniently, through several self-supply options (e.g. wells, rivers, harvesting rain-water). The latter option has more risks attached to it and it is usually not practical since pre-treatment facilities need to be set up. The amount of water used is influenced by the type of washing machine, the type of textile being laundered, the type and amount of dirt/stains and the number of cycles for each main stage (e.g. rinsing requires the highest amount of water used, which must also be fresh water) (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.). The typical overall water usage in the laundry industry is:

Washing	90-92%
Boiler	5-8%
Ancillary	2-3%

c. Chemicals

Chemicals play an integral role during the laundering process. Given the difficulty of removing certain chemicals in wastewater by municipal wastewater treatment facilities, as well as the toxicity, flammability and environmental impact these products have, chemical suppliers have started developing improved and alternative formulations. These products tend to have a less detrimental environmental impact, decreased health and safety risk and functionality at lower pH and temperatures (Seneviratne, 2007).

d. Labour and maintenance

In the laundry industry, labour accounts for almost 50% of the operating costs. These costs decrease with the degree of automation.). Well maintained equipment can save on water and energy usage and costs.

2.2 SIZE OF THE INDUSTRY

Several research articles have been produced globally regarding the water and wastewater management of laundries, but the coherence and consistency of information published is as variable as the regions in which these studies took place. The daily wastewater discharge, for example, of a laundry can range from 200 m^3 (Princes Fabricare Commercial Laundry Case Study, n.d.) to 400 m^3 (Ciabitti *et al*., 2009). The wastewater that laundries produce commonly contain high levels of suspended solids (SS) (>1000 mg/L), chemical oxygen demand (COD) (up to 20 000 mg/L)), biological oxygen demand (BOD) (>1300 mg/L), FOGs (>1100 mg/L), as well as heavy metals and organic solvents (Janpoor *et al.*, 2011; Gosolits, 1999). In xxx it was shown that about 10% of all municipal sewage discharge originates from laundries (Janpoor *et al.,* 2011). 15 L of water is typically required to launder 1 kg of textile (Ciabitii *et al.*, 2009). These figures are, at best, an estimation of the current water and wastewater flows in an average laundry. The general consensus is, however, that there is room for global improvement in the water and wastewater management practices in laundries, especially concerning the impact these factors have on the environment and municipal facilities. The following paragraphs indicate available data relating to the laundry industry that have been published by various countries or geographic regions.

2.2.1 South Africa

There is limited data regarding the water and wastewater practices of laundries in South Africa. This lack of data is partly due to there being no association or organisation which represents the South African laundry industry. A few large commercial laundries are operational in South Africa, of which The Bidvest Laundry Group is the most prominent regarding operational statistics, and data made available by this group is mentioned in the last paragraph of this section.

The Bidvest Laundry Group is at the forefront of the local laundry sector, with facilities in Cape Town, Durban and Johannesburg. The company is made up of three divisions: First Garment Rental (supplier of overalls and work-wear), Montana Laundries (provider of OPLs, laundry equipment and maintenance) and Boston Launderers. Boston Launderers claim to be the biggest commercial laundry operating in the country. The Bidvest Laundry Group uses machines which have a favourable efficiency, economic and environmental impact. The current CBWs they use are being replaced by new "Pulse Flow CBWs" (manufactured by Milnor Laundry in Belgium), which have a SWI of up to
4.2 L compared to the current 15 L (CBW Batch Washers, n.d.).

2.2.2 The European Union

The European Union (EU) is at the forefront of innovation regarding the laundry industry. They have several projects and structures in place to optimise the water and wastewater practices at laundries. An example of such a project is SMART Laundry 2015, which aims to reduce the average SWI of the laundry industry to 14 L/kg, as well as reducing the total water use by 70% to 10.4 Mm^3 by 2015. This is a dramatic decrease in water use, since the EU laundry industry SWI was estimated to be 21 L/kg in 2008. This industry consists of about 11 000 laundries, which launder 2.7 billion kg of textiles annually and use as much as 42 Mm^3 of water per year (Hloch *et al.*, 2012).

The European Textile Services Association has reported (European Textile Services Association, 2014) that the EU laundry industry has improved its sustainability due to the following developments:

- CBWs now use process integrated water and heat recovery systems.
- A general trend, similar to what happened in the construction industry, is the use of heat exchangers (air to air/air to water/water to air) and heat pumps.
- Traditional boiler houses, used to produce steam, are being replaced with direct water heating systems.
- Gas heated tumble dryers and ironers generate significant fuel savings due to the more efficient use of gas, when used directly in the device that needs heating, while the production and transportation of steam can be avoided.

- Recent improvements in the detergents used allow for lower temperature washing, where disinfection is achieved by chemical means rather than high temperatures.
- The use of renewable energy sources (e.g. solar energy) is fairly new, but will play a much bigger role in the future.

A recent survey conducted (Gruttner, 2013), representing 32 workwear laundries across Europe, compared their environmental impact between 2007 and 2011, indicating the following:

- Oil and gas consumption was reduced by 13%
- Electricity consumption was reduced by 5%
- The reduction in water consumption has stabilised around 14-15 L/kg
- Consumption of chemicals increased by 18%

2.2.3 The United Kingdom

In the United Kingdom (UK), which is an EU member, the laundry industry is described as including the rental of textiles. This makes up 80% of its market, with 90% of the industry's total energy being attributed to the laundering process. The industry comprises 134 laundry sites, which is dominated by Johnsons Apparelmaster (19 laundries) and The Sunlight Group (40 laundries). The UK laundry industry launders about 743 651 tons of textiles annually (Industrial energy efficiency accelerator, n.d.).

2.2.4 The United States of America

The United States of America (USA) has about 1 000 commercial laundry companies, excluding laundromats (Dry cleaning and laundry facilities, 2005). The laundering process uses 85% of the industry's total water use, with ancillary (4%) and heating and other processes (11%) making up the rest (East Bay Municipal Utility District, 2008). The Environmental Protection Agency (EPA) of the USA last conducted a comprehensive study of the laundry industry in 1994. This report is not accessible, but some of its findings are revealed in subsequent EPA documents (Environmental Protection Agency, 1997; Environmental Protection Agency, 2000). They surveyed 193 commercial laundry facilities in the USA, of which the data was extrapolated to represent the 1 747 operational laundry facilities in the country. More than 95% utilised WEs, whilst only 2.23% reported using CBWs. They indicated that the laundering process used 92.1% of the industry's total water use, with ancillary (3.1%), heating (1.8%) and other processes (3%) making up the rest. It is important to note that since 1994, the laundering process has been optimised regarding machinery and techniques, with water usage down from 92.1% to 85% of the industry's total water usage (Environmental Protection Agency, 2000). Other information obtained by the 1994 EPA study includes that the amount of wastewater discharged was 22.87 L/kg, and that 87% of laundries did not have any wastewater treatment systems in place (Environmental Protection Agency, 1997).

2.2.5 Other regions

Large commercial laundries in Australia which launder industrial textiles use up to 80 000 kL of water per year. They launder large volumes of textiles – up to 90 t/week (Brown, 2009). In Hong Kong the laundry industry uses as much as 53% of the total commercial water usage (Lu & Leung, 2003). It was even reported that a hospital laundry in Brazil had a SWI of as much as 35 L/kg (Kist *et al*., 2008).

2.3 OVERVIEW OF DOMESTIC LAUNDERING

As mentioned previously, this national survey document is not concerned with actively visiting and evaluating the domestic laundry sector. It is, however, important to mention household laundering, since this also has a significant impact on our water resources, environment and municipal wastewater treatment facilities. A typical household (with piped water supply and sewage system) in South Africa uses between 4% and 22% of household water for laundering purposes. Every person uses on average about 52 L of water for laundering every day (Murphy, 2006). This means that, along with other regions, South Africa has a significant amount of water usage attributed to domestic laundering.

Domestic laundry practices vary from region to region, where different machines, conditions (e.g. temperature) and amount of cycles are used. Table 2.1 compares domestic laundry characteristics between different regions:

Table 2.1: Household laundry characteristics in different regions (adapted from Pakula and Stamminger, 2010)

Region	Type of washing machine	Average load size (kg/wash)	Wash temperature (°C)	Water use (L/wash)	Number of washes per household per year	Total water use per household per year (kL)
Western Europe	>98% Front	3.5	40	60	165	9.9
Eastern Europe	>98% Front	3.5	40	60	173	10.4
Turkey	>90% Front	*	60	60	211	12.7
North America	>98% Top	3.5	15-48	144	289	41.6
Australia	>68% Top	*	20-40	106	260	27.6
China	>90% Top	1.65	Cold wash	99	100	9.9
South Korea	>90% Top	*	Cold wash	140	208	29.1
Japan	>97% Top	3	Cold wash	120	520	62.4

*Not determined

In Europe only horizontal axis machines are used, therefore they use less water per wash cycle than America, Australia and Asia, which use mainly vertical axis machines. China, however, annually consumes as little water as European households due to their low number of wash cycles. Japan uses high amounts of water annually due to using vertical axis machines and having a high number of wash cycles (Pakula and Stamminger, 2010). A quarter of total domestic wastewater in South Korea originates from domestic laundering (Seo *et* al., 2001). An average water consumption of 106 L per wash cycle has been calculated for Australian household washing machines (Australian Bureau of Statistics, 2008). This is due to their use of primarily vertical axis washing machines. About 20% of overall Australian household water use is from laundry (Chen *et al*., 2013). The USA attributes about 21% of its domestic water consumption to household laundering (Shove, 2003).

2.4 CATEGORISATION OF THE LAUNDRY INDUSTRY IN SOUTH AFRICA

A review of available literature has revealed that there are currently no universal criteria for categorising laundries. Categorising laundries can be related to physical size, textile load capacity or the type of clients and textiles the laundry caters for. Table 2.2 (following page) summarises the available information in literature which relates to defining laundries under specific categories.

2.5 MAIN STAGES IN LAUNDRY PROCESSES

Concerning the actual laundering process, all industrial and commercial laundries rely on three main stages: pre-wash, main wash and rinsing (

Table 2.3, following page). Each laundry has its own policy regarding the amount of cycles used for each stage. After the main laundering stages a final finishing step is applied, which includes drying (extraction of residual moisture) as well as the possible application of additives such as softeners or starch (dependent on the type of textile and client preferences) (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

Table 2.2: Information available regarding the categorisation of laundries

Laundry category	Criteria type	Description	Reference
Low-capacity	Load capacity	Up to 1.5 t/day (300-500 kg/8 hour shift). Washing machines have capacities of up to 12 kg. Launders textiles from hotels, residences, cafeterias, etc. Most common type in Europe.	(Máša *et al.*, 2013)
Large commercial	Load capacity	3-50 t/day. Some provide rental services. Include industrial textile (heavy wear) laundries. Mainly uses CBWs.	Environmental Dossier on Professional Laundry, n.d; Brown, 2009
Large on-premise laundries (OPLs)	Load capacity	0.5-3 t/day. Usually own laundered textiles. Very few provide service to external clients. Located at hotels, hospitals, mines, factories, etc. Uses WEs.	Seneviratne, 2007
Small OPLs	Load capacity	Up to 0.5 t/day. Usually own laundered textiles. Very few provide business to external clients. Located at nursing homes, retirement villages, motels, etc. Uses WEs.	Seneviratne, 2007
Hospital (Large)	Load capacity; Textile type	3-30 t/day. Facilities are specialised to handle textiles containing blood, urine, faeces, pathogens, pus and medicine. Mainly uses CBWs.	Environmental Dossier on Professional Laundry, n.d.
Laundromats	Load capacity; Client type	2-4 t/week. Operated by members of public. Uses coin-operated/manually operated WEs	Brown, 2009

Table 2.3: The three main stages associated with the laundering of textiles in the laundry industry (Training Modules on the Sustainability of Industrial Laundering Processes)

Main stages	Function	Description
Pre-wash	Initial rapid wetting of textile	Prepare textiles for main wash
	Removal of most dirt and stains	
Main wash	Removal of remaining dirt and stains	Removal requires more intensive chemical, thermal and mechanical action which water-based pre-wash cannot provide
	Chemical and thermal disinfection	pH of >11 is maintained
	Bleaching	Removes stains, enhances whiteness and provides chemical disinfection
Rinsing	Removal of residual dirt and chemicals used	Clean water required
	Neutralisation (“Souring”)	Reduces pH of the water to neutral by adding acids (usually in final rinsing cycle). This minimises textile damage and skin irritations.

2.6 CHEMICALS AND PRODUCTS USED IN LAUNDRY PROCESSES

2.6.1 Chemicals used and their functions

The laundry industry makes use of several different chemicals in order to improve the effectiveness of the cleaning cycle, reduce energy and water costs and improve the lifetime of the machinery used. These chemicals include alkalis/builders, antichlors, bleaches, softeners, sours, starches and a variety of detergents (OECD, 2011).

2.6.1.1 Detergent formulae

A detergent is not a singular homogeneous species, but rather a formulation of different types of chemicals. The primary compound in detergents is builders and surfactants, whilst complementary chemicals include anti-redepositing agents, bleaches, brighteners, corrosion inhibitors, enzymes, fabric softeners, fragrances, hydrotopes, preservatives, solvents and stabilisers (USEPA, 1999). In many cases, depending on the laundry, the complementary chemicals may form part of a separate product that is added to the washing cycle separately from the detergent; this is primarily the case with bleaches, builders and fabric softeners. An approximate composition for detergents used in small laundries the U.S.A can be seen in Table 2.4:

Table 2.4: Detergent chemical composition (USEPA, 1999)

Component	% in Formulation
Builders	58
Surfactants	36
Bleach, brighteners, enzymes	2.5
Fragrances and fabric softener	1.5
Others	2

2.6.1.2 Surfactants

Surfactants are chemicals that reduce the surface tension of the water, thereby increasing the contact between the fabric to be cleaned and the water. Surfactants play a small role in removing the soil from a fabric that is being cleaned, instead, the main purpose of surfactants are to suspend the soil once removed. There are several different types of surfactants, each with different properties:

- **Anionic:** These surfactants have a negative charge which can resist the effects of water acidity and hardness (USEPA, 1999). Examples of anionic surfactants are sulphated fatty alcohols and sulfonated amides (OECD, 2011).
- **Non-ionic:** These surfactants have no charge and are the most commonly used surfactants in laundry detergents (Dunlap, 2001). They are effective in removing oily soil from fabrics. Examples of non-ionic surfactants include ethylene oxide or propylene oxide with fatty alcohol, fatty acid condensates with ethylene oxide, amides from fatty acids and di-ethanolamine, and condensate of ethylene oxide with an amine or amide (OECD, 2011).
- **Cationic:** These surfactants are positively charged and are more often than not used in fabric softeners and antibacterial agents rather than detergents (OECD, 2011). Cationic surfactants are commonly used with non-ionic surfactants, but never with anionic surfactants since the two charges will attract one another and agglomerate, eventually precipitating out of solution (USEPA, 1999). Examples of cationic surfactants are mostly quaternary ammonium salts.
- **Amphoteric:** These surfactants have the ability to act either as an acid or base (displaying either a positive or negative charge) which makes them well suited as recyclable cleaners because they exhibit low foaming properties, provide good detergency and compatibility with alkaline formulations. They also exhibit good water solubility (USEPA, 1999)

Detergents typically used at industrial or commercial laundries will contain a surfactant at over 90% concentration (CEB, 2006). This is in contrast with the information shown in Table 2.4 since those values are for formulations used in smaller laundries.

2.6.1.3 Builders

Builders are chemicals (alkalis, water softeners and anti-redepositing agents) that can either be added to a detergent formulation, or to the wash load directly. The main purpose of builders is to increase the performance and effectiveness of surfactants by increasing the water alkalinity, softening the water, and preventing redepositing of the soil back onto the fabric being cleaned.

- **Alkalinity:** Increasing the alkalinity also increases the pH of the wash water. This improves the effectiveness of the surfactant and allows the cellulosic fibres to swell, aiding in the removal of soil.

Detergent formulations and separate products may contain between 30-85% alkalis (OECD, 2011). Alkalis such as hydroxides, silicates, carbonates and phosphates are typically used by the laundry industry.

- **Hardness:** Ions like Calcium and Magnesium (responsible for hardness in the water) can reduce the effectiveness of a surfactant. These ions interact with the surfactant directly or they interact with the negative charges on the fabric or soil, either way, reducing the electric repulsion between them (Kirk-Othmer, 2004). Water softeners simply arrogate these ions and prevent their interaction with the surfactant. Water softeners in detergent formulations or separate products account for 15-55% of the formulation (OECD, 2011). It should be noted that the above mentioned percentages are based on phosphate content, which acts as both a water softener and an anti-redepositing agent. Other water softeners include phosphates, zeolites, sodium carbonate, sodium silicate, sodium citrate, ethylenediaminetetraacetic acid (EDTA) and nitrilotriacetic acid (NTA) (Kirk-Othmer, 2004).
- **Anti-redepositing:** After removing the soil from the fabric and suspending it in the wash water, it is important to ensure that the soil does not simply redeposit on to the fabric at a later stage whilst still in the machine. Anti-redepositing agents are used to keep the soil in suspension in order to keep it from redepositing onto the fabric. Builders with multiple charges are most effective in preventing redepositing. In common detergent formulations and separate products, builders typically contain less than 5% anti-redepositing agents (OECD, 2011). Examples of anti-redepositing agents include polycarboxylates, polyacrylates, polyethylene glycol, sodium silicate and polyaspartic acid.

Builders and alkalis can be added to a washing machine as part of a detergent formulation (most common), or they can be added separately in an additional product (typically done when the supply water is especially hard or acidic). When it comes to commercial and industrial laundries, builders may have their own formulation in addition to the formulation of the detergent (OECD, 2011).

2.6.1.4 Other components in detergent formulae

Many other components may be found in typical detergent formulae (which are not added as additional products). A few are mentioned here for discussion:

- **Antimicrobial Agents:** These agents are used to reduce or inhibit microbial growth. Examples of antimicrobial agents used in detergents include pine oil, quaternary ammonium compounds, sodium hypochlorite, hydrogen peroxide, triclocarban and triclosan.
- **Optical Brighteners:** These additives absorb invisible ultraviolet light and emit it as visible light within the blue light spectrum (USEP, 1999). The effect of the blue tint in contrast to the yellow tint found in off-white fabrics results in a greater whiteness from the fabric. The use of brighteners only apply to cotton fabrics and are best applied at high temperatures. Examples of optical brighteners include stilbene disulfonates and coumarin derivatives.
- **Enzymes:** Enzymes are used as a catalyst to facilitate in the destruction of soil particles and stains. The enzymes are classified as proteins that include protease, amylase, lipase and cellulose (USEPA, 1999). Most enzymes are used with non-ionic surfactants since anionic and cationic surfactants lower the stability of the enzymes.
- **Corrosion Inhibitors:** These compounds help protect the various metal parts of the washing machines. The most common corrosion inhibitor used in detergents is sodium silicate (USEPA, 1999).
- **Fragrances:** Since detergents contain many different chemicals, it is important to mask the odour of these chemicals using fragrances. It should be noted that fragrances are more typically used in consumer laundry applications, rather than commercial laundries (UTSA, 2005).
- **Hydro-tropes:** Hydro-tropes are used to prevent the separation of the different detergent constituents into different phases, thereby promoting uniformity within the detergent solution. Examples of hydro-tropes include glycols, toluene sulfonates and cumene sulfonates (USEPA, 1999; UTSA, 2005).
- **Preservatives:** There are two types of preservatives; those who prevent the deterioration of the detergent product (in-can preservatives), and those who prevent the oxidation, discoloration and bacterial growth on the fabric (USEPA, 1999). Examples of in-can preservatives include butylated

hydroxytoluene, ethylenediaminetetraacetic acid (EDTA), bronopol, formaldehyde and isothiazolinones. Fibre preservatives are less common in detergent formulations.

- **Stabilisers and Suppressors:** These compounds are used to stabilise and/or prevent excessive sudsing. Examples of stabilisers include alkanolamides and alkylamine oxides (USEPA, 1999). Suppressors that are used to prevent excessive detergent sudsing include silicone, soap, and alkyl phosphates.

2.6.2 Phosphates in laundry detergents

Concentrated phosphates are used in detergents to:

- Counteract hardness in the water (prevent Ca and Mg deposits on clothes)
- Increase the surface activity of the active washing compounds
- Cause ions in the dirt and textile fibres to become more strongly charged. This in turn leads to increased repulsion between the ions in the dirt and in the textile, thus increasing washing performance
- Break up large particles of e.g. mud or clay into smaller ones
- Emulsify oily materials
- Re-dissolve Ca and Mg compounds from detergent in previous washes and reactivate any remaining soap.

2.6.3 Alternatives to phosphates in detergents

- **Sodium citrate**
  - Considerably more expensive
  - Does not perform as well in removing Ca and Mg
- **Ethylene diamine tetraacetic acid (EDTA) and Nitrilotriacetic acid (NTA)**
  - Less effective as a particle disperser
  - The main problems with NTA are that there has been some evidence that it is carcinogenic and its great strength in combining with metal ions has caused fears that heavy metals in sewage sludge may be taken up and hence mobilised. Both EDTA and NTA being excluded from EU Ecolabelable automatic dishwasher and domestic laundry detergents
- **Zeolite A and its cobuilders**
  - Relatively inert substance derived from aluminium oxide
  - Reasonable performance in abstracting calcium and magnesium ions, but is limited as a builder.
  - It does not buffer during the washing process
  - It does not prevent redeposition of soil particles in the wash liquid, so it has to be used with a cobuilder, usually polycoarboxylic acids (PCA).

2.6.4 Bleaches

Bleaches are also used to remove the colour of stains and can solubilise stains for easy removal (USEPA, 1999). Laundry bleaches can be either oxidising or reducing, thereby removing or adding electrons to the stains, respectively. Oxidising bleaches are typically chlorine based or oxygen based, although the oxygen based bleaches are less effective and require higher temperatures, alkalinity and concentration to perform sufficiently (USEPA, 1999). Oxygen bleaches can, however, achieve better whitening. Examples of oxygen based bleaches include hydrogen peroxide, perborates and peracids, whilst the most common chlorine based bleaches include sodium hypochlorite.

Examples of reducing bleaches include sulphur dioxide, sulphites and bisulphites (Kirk-Othmer, 2004). Again it is found that most consumer detergent formulations contain small amounts of bleach; in commercial laundries, a separate bleach formulation is used for white cotton loads. Commercial laundries typically use sodium hypochlorite at concentrations less than 12% in water.

2.6.5 Antichlors, acids (sours), softeners and starches

These products do not have any effect on removing soil or stains from the laundered fabrics and are typically added directly to the washing machine prior or during the last rinsing cycle. The purpose of these products is mainly to neutralise the chemicals added for cleaning the fabrics. These products may be added separately, or as a finalising formulation. Each of these products are listed below for discussion:

- **Antichlors:** These products are used to remove excess bleach (only chlorine based bleaches) by neutralising the remaining chlorine (Evans Vanodine, 2003).
- **Sours (Acids):** Sours are added to lower the pH of the water during the final rinsing cycle. This is done since alkaline builders, which increase the pH, may have been used previously during the washing cycle. Lowering the pH to proper levels is important for preventing the yellowing and hardening of the fabrics and also reduce skin irritation when handling the fabrics (Evans Vanodine, 2003). If the laundry recycles this water back to the washing cycle, some alkalinity may be kept in the water (USEPA, 1999). Sours are also used to remove rust and prevent Iron from depositing.
- **Softeners:** Softeners (not to be confused with water softeners that counteract hard water) are used to soften laundered items and control static electricity that may build up on laundered items. Cationic surfactants are often used as softeners by laundries since they bind strongly to the negatively charged fabric surfaces, thereby creating a lubricating film on the surface of the fabric, increasing the flexibility and softness of the fabric.
- **Starches:** Starches can be added to the final rinse cycle or can be sprayed onto the fabrics prior to ironing. Starches help to stiffen the fabric, allowing it to hold its shape for longer and providing a smooth, crisp, finish once ironed. Soil and stains are also prone to adhere to the starch rather than the fabric, thereby easing their removal during future washing.

2.6.6 Physical properties of laundry chemicals

The majority of cleaning chemicals used in the laundry industry are water soluble neat solids. The physical properties of chemicals that were chosen as representatives of each additive category can be seen in Table 2.5. It should be noted that the properties of the chosen compounds do not reflect the physical properties of the other chemicals in the given category.

2.6.7 Fate of laundry chemicals

The use of chemicals in the laundry industry is inevitable, but this does not mean that the fate of laundry industry effluent is guaranteed to lead to problems in subsequent wastewater treatment plants and further environmental pollution. Depending on the characteristics of the chemicals used as well as the processes used within the laundry industry, the fate of these chemicals lies along four possible pathways which may or may not lead to environmental impacts (ETSA, 2010):

- The chemicals may completely biodegrade (ending up as CO_2 and H_2O) in the WWTP
- The chemicals may be absorbed into the sludge of the WWTP (being disposed as solid waste)
- The chemicals may be discharged with the final effluent from the WWTP (into the environment)
- The chemicals may evaporate during treatment at the WWTP

With the above points in mind, and looking at the physical properties of the chemicals (see Table 2.5) used by laundries, it can be assumed that a very small amount, if any, of compounds will follow the fourth pathway listed above (ETSA, 2010). This is because there are few volatile organic compounds (VOCs) and other compounds listed that are likely to evaporate. Additionally, they will likely evaporate prior to reaching the WWTP since the laundry water is typically at a much higher temperature than that of the WWTP.

The other chemicals that are used in small quantities include a few salts and some polymers. The salts will likely disassociate completely during treatment at the WWTP and will either enter the environment or attach to the sludge which will be removed in the form of solid waste. The polymers will likely also attach to the sludge to be removed as solid waste, or will biodegrade into simpler, and even mineral compounds. In either case, the effects of these compounds are minimal due to the effective removal or treatment at WWTPs, or due to their low quantities.

Table 2.5: Physical properties of laundry chemicals (adapted from OECD, 2011)

Additive Category	Chemical (CAS)	Physical State	Molecular Weight	Vapour Pressure (torr at 25°C)	Boiling Point (°C)	Melting Point (°C)	Water Solubility (g/L)
Anionic Surfactant	Dodecylbenzene sulfonic acid, sodium salt (25155-30-0)	Solid	348.48	2.29E-15	n/a	n/a	0.8
Non-ionic Surfactant	Poly(oxy-1,2-ethanediyl),alpha-(4-nonylphenyl)-omega-hydroxy-,branched (127087-87-0)	Liquid	396	<0.01 at 20 °C	>200	n/a	5
Cationic Surfactant	Dimethyloctadecel benzyl ammonium chloride (122-19-0)	Solid	424.15	Salt (VP negligible)	n/a	n/a	Soluble
Amphoteric Surfactant	Cocamidopropyl Betaine (61789-40-0)	Liquid	n/a	n/a	>100	-8	Soluble
Alkali	Sodium Hydroxide (1310-73-2)	Solid	40	1.82E-21	1390	318	1000
Water Softener	EDTA (60-00-4)	Solid	292.25	4.98E-13	Decomposes	Decomposes	0.5
Anti-Redepositing Agent	Sodium Hydroxide (1310-73-2)	Solid	122.06	5.01E-17	n/a	n/a	Soluble
Antimicrobial Agent	Alkyl dimethyl benzyl ammonium chloride (68391-01-5)	Solid	n/a	Salt (VP negligible)	n/a	n/a	Soluble
Optical Brightener	7-dietylamonio-4-methylcoumarin (91-44-1)	Solid	231.29	n/a	n/a	68-72	Soluble in aqueous acid solutions
Enzyme	Amylase (9000-92-4)	n/a	Amylase is a class of enzymes that convert starch into sugars. Physical properties are not easily characterized.				n/a
Corrosion Inhibitor	Sodium Metasilicate (6834-92-0)	Solid	122.06	5.01E-17	n/a	1089	1000
Fragrance	Benzyl Acetate (140-11-4)	Liquid	150.18	0.177	213	-51	3.1
Hydro-trope	Polyethylene Glycol (25322-68-3)	Liquid	Polyethylene glycol is a polymer, which typically have high molecular weights, low vapour pressures, and high melting and boiling points.				Soluble
Preservatives	Butylated hydroxytoluene (128-37-0)	Solid	220.35	0.00516	265	70	Insoluble
Stabiliser/Suppressor	N,N-Dimethyldodecylamine Oxide (1643-20-5)	Solid	229.41	6.23E-08	n/a	132	190
Oxidising Bleach	Sodium Hypochlorite (7681-52-9)	Solid	74.44	1.03E-13	n/a	18	29.3
Reducing Bleach	Sodium Bisulfate (7631-90-5)	Solid	104.03	Salt (VP negligible)	Decomposes	Decomposes	Soluble
Antichlor	Sodium Thiosulfate (7772-98-7)	Solid	158.11	Salt (VP negligible)	Decomposes	48	Soluble
Sour	Phosphoric Acid (7664-38-2)	Liquid	98	0.03 at 20 °C	158	21	Miscible at all proportions to H2O
Fabric Softener	Dimethyloctadecyl benzyl ammonium chloride (122-19-0)	Solid	424.2	Salt (VP negligible)	n/a	n/a	Soluble
Starch	Starch (9005-25-8)	Solid	Starch is a high molecular weight carbohydrate polymer found naturally in plants. Physical properties are not easily characterised.				Insoluble in cold water, gels in hot water

n/a = Not available

Table 2.6 (following page) shows the different chemicals and products that are used in the laundry industry washing and cleaning processes.

Table 2.6: Different type of chemicals and products used in the laundering process (Training Modules on the Sustainability of Industrial Laundering Processes)

Chemicals/products used for laundering	Description of function in laundering	Common example
Surfactant	Rapidly wets the textile	Alkyl benzene sulfonates
	Removes dirt then suspends it in water	
	Suspends oil	
Builders	Softens water (removes calcium and magnesium ions)	Sodium tri-polyphosphate; Sodium carbonate; Zeolites
	Enhance action of surfactants	
	Provides alkalinity (assists in dissolving oily dirt)	
Alkalis	Provides alkalinity (assists in dissolving oily dirt)	Sodium silicate; Potassium silicate
Anti-redeposition agents	Prevents re-deposition of suspended dirt	Carboxy-methyl cellulose
Enzymes	Removal of stains	Proteases; Amylases; lipases
	Can smooth cotton fabrics	
Bleach	Whitening and brightening of textiles	Sodium hypochlorite; Sodium percarbonate
Disinfectants	Kill or inhibit microbial growth on textiles	QACs – quaternary ammonium compounds
Fabric softeners	Soften and smooth textiles	Cationic surfactants
	Reduce wrinkling and static electricity	
Fragrances	Neutralise inherent odour of detergents	Petroleum-based artificial fragrances
Optical brighteners	Gives whiter and brighter appearance to textiles	Amino-triazines
Preservatives	Prevent liquid detergent spoilage during storage	Glutaraldehyde
Solubilisers	Prevent gel and layer formation of liquid detergents	Xylene sulfonate
Foam regulators	Inhibit sud/foam formation	Siloxane- and paraffin-based products
Corrosion inhibitors	Inhibit corrosion of metallic parts	Sodium silicate

The majority of the chemicals that enter the WWTP that services the area containing the laundries will be from detergents. This is not only because detergents are the only product that will definitively be used at all laundries (the other products are optional depending on the laundry clients), but also because detergents are used in much higher quantities than the other products. Fortunately, the majority of compounds found in detergent formulations are biodegradable and will likely follow the first pathway noted above (ETSA, 2010).

There are, however, compounds that do not biodegrade fast enough, or that biodegrade, but produce a secondary product that also has environmental implications. These products will likely follow the third pathway as noted above. Of these compounds, phosphate is the most likely to cause environmental problems. This is due to the fact that phosphate is not effectively removed by WWTPs that are not specifically designed for phosphate removal, but also because phosphate is used in larger quantities than other compounds.

The reason why phosphate is so often used in detergents is mainly due to its versatility. Where some compounds may only fall in one of the additive categories for detergent formulae, phosphate based compounds fall under many additive categories (especially as builders). Phosphates can be used for water softening, alkalinity, pH control, anti-redepositing, souring, stabilising and suppressing. The physical properties of phosphates also make them favourable for production and use in detergents.

Unfortunately, phosphate can have severe environmental impacts (eutrophication) and have since been reduced and even removed from detergent manufacturers that are trying to conform to a more environmentally conscious market (Environmental Leader, 2015).

2.7 WASTE PRODUCTS

The third element that is associated with the laundering process is waste products, which includes both wastewater and gas emissions. The water that laundries use in the main processes is exposed to a variety of chemicals, external conditions and textiles. The wastewater that is ultimately generated is of great concern, since its components, besides raw water, include a variety of compounds that need to be treated (usually by a municipal wastewater treatment facility). The wastewater can contain salts, phosphates (from detergents), soil, FOGs (fats, oils and greases), heavy metals, residual textile material, heat, microbes and process by-products (such as adsorbable organically-bound halogens formed by soil-detergent-water reactions). Laundries employing recycling of rinse water for wash water generally have a higher concentration of contaminants in their final wastewater. Environmental concerns (e.g. eutrophication) and municipal regulations (e.g. tariffs) are associated with the concentration levels of these constituents. Gas emissions are usually negligible when compared to other large industries. The gases that are emitted (e.g. carbon dioxide) from the use of fossil fuels (e.g. laundries using coal-fired boilers) usually fall under this category (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

2.8 TYPES OF WASHING MACHINES USED

There are two types of washing machines used in the laundry industry (Figure 2.3): washer-extractors (WEs) and continuous batch washers (CBWs, sometimes called tunnel washers).

Although being much larger, WEs work similar to a domestic washing machine, since items are being laundered in batches and the process takes place in one cylinder. The main body of a WE consists of an outer case, which is an immovable tank fitted with a door for loading and unloading. Inside this outer case is a perforated cylinder (inner drum) that can hold wash loads and rotate. It also has a reversing mechanism which allows it to make revolutions in both directions to avoid the load becoming tangled. This drum can have several different designs and rotates around either a vertical axis (known as a top loader) or a horizontal axis (known as a front/side loader). The latter is the most popular type and tends to use less water per cycle, since most of the drum capacity needs to be filled when using top loaders.

Figure 2.3: (Left) a washer-extractor; (Right) a tunnel washer/continuous batch washer

(Training Modules on the Sustainability of Industrial Laundering Processes)

Top loaders are less expensive, but front loaders have lower running costs and are therefore more economically viable. There are also a variety of other basic components which differ according to the supplier, such as heating elements, inlet and outlet valves for water and steam, and computerised laundering control systems. The laundering process program steps include adjustable settings for the following stages: pre-wash, main wash, rinsing, neutralisation (during last rinse cycle) and a final spin to mechanically extract water (Leonardo da Vinci project). WE machines aim to achieve a specific water intake (SWI) of 17-22 L/kg (Brown, 2009).

Continuous batch washers are used by larger, high-volume (*i.e.* processing > 10 tons of textiles per week) laundry facilities. These machines are much more expensive than WEs and require lots of space. They provide a more continuous flow of water and textiles and they do not have to be stopped for loading and unloading. These machines consist of a series of internal compartments in which a large auger/corkscrew slowly turns to move the textiles automatically through each compartment. Water used in one compartment is used in a previous compartment, excluding the rinsing zones, which require fresh water. This means that the flow of water is opposite in direction to the textiles (*i.e.* the water flows from compartments containing the clean textiles towards compartments containing the dirty textiles, after which the water is discharged into the drainage system). This internal re-use of water maximises water efficiency (Brown, 2009). Inner drums in CBWs differ in diameter and volume. Oscillating cylinders can be used, although rotating cylinders are more popular and tend to increase the efficiency of the washing and rinsing stages. Similar to WEs, CBWs have computerised laundering process program controls which include adjustable settings for the following stages: pre-wash (2-4 compartments), main wash (3-6 compartments), rinsing (2-6 compartments) and neutralisation (1-2 compartments). CBW machines aim to achieve a SWI of 7.5-12.0 L/kg (Brown, 2009).

CHAPTER 3: REGULATIONS

3.1 WASTE HIERARCHY PRINCIPLES

South Africa has a three-tier system of government, i.e. national, provincial and local spheres of government. In general terms, national government is responsible for high level security functions, economic regulation and social development; the provincial government for regional economic planning, housing, environmental management, rural livelihoods and human development; and local government for basic service provision (which links closely with housing) and for creating an enabling environment for local business (Sutherland, 2013).

The relationship between these three spheres of government is based on a system of co-operative governance defined in the Constitution. Co-operative governance requires that each sphere respects the powers and functions of other spheres, cooperates with each other and coordinates actions and legislation (SA Government, 1996).

On a local level, governance takes place through municipalities such that all areas, including urban and rural, fall under local municipal control. There are three types of municipalities – metropolitan, district and local municipalities (as defined by the Municipal Demarcation Act). The largest metropolitan areas are governed by Metropolitan municipalities which have exclusive municipal executive and legislative authority in their respective areas, while the rest of the country is divided into district municipalities, each of which consist of several local municipalities. There are eight metropolitan municipalities, 44 district municipalities and 226 local municipalities within South Africa (Yes!Media, 2015).

3.2 LEGISLATION

3.2.1 National Policy for Water, Effluent and the Environment

The Bill of Rights in the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) enshrines the concept of sustainability; specifying rights regarding the environment, water, access to information and just administrative action. These rights and other requirements are further legislated through the National Water Act (NWA), 1998 (Act 36 of 1998). The latter is the primary statute providing the legal basis for water management in South Africa and has to ensure ecological integrity, economic growth and social equity when managing and using water.

The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat). The IWRM approach provides for both resource directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment. Examples of resource directed actions are the formulation of resource quality objectives and the development of associated strategies to ensure ongoing attainment of these objectives; catchment management strategies and the establishment of catchment management agencies (CMAs) to implement these strategies.

On the other hand, source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms. The integration of resource and source directed measures forms the basis of the hierarchy of decision-taking aimed at protecting the resource from waste impacts. This hierarchy is based on a precautionary approach and the order of priority for water and waste management decisions and/or actions are shown in Figure 3.1.

RESOURCE PROTECTION AND WASTE MANAGEMENT HIERARCHY
Step 1: Pollution Prevention
↓
Step 2: Minimisation of Impacts
Water reuse & reclamation Water treatment
↓
Step 3: Discharge or disposal of waste and/or wastewater
Site specific risk based approach Polluter pays principle

Figure 3.1: Hierarchy of decision making to protect water resources (DWS, 2015)

The overall Resource Protection and Waste Management Hierarchy sets out the interpretation of policy and legal principles as well as functional and organisational arrangements for resource protection and waste management in South Africa. Operational policies describe the rules applicable to different categories and aspects relating to waste discharge and disposal activities.
Further information on some of the relevant policies is provided in this section.

3.2.2 Water policy

The recently formed Department of Water and Sanitation (DWS, 2014 – formerly the Department of Water Affairs (DWA) and the Department of Water Affairs and Forestry (DWAF)) is the water and sanitation sector leader in South Africa. DWS is the custodian of South Africa's water resources and of the National Water Act (Act 36 of 1998) (DWAF, No. 36 of 1998: National Water Act, 1998., 1998) and the Water Services Act (Act 108 of 1997) (DWAF, No, 108 of 1997: Water Services Act, 1997., 1997). DWS is also the national regulator of the water services sector.

The National Water Act provides the legal framework for the effective and sustainable management of water resources within South Africa. The Act aims to protect, use, develop, conserve, manage and control water resources as a whole, promoting the integrated management of water resources with the participation of all stakeholders (DWAF, n.d.).

The Act stipulates the requirements for, among others, the development of a National Water Strategy and Catchment Management Agencies, the protection of water resources through classification, setting reserves (basic human need and ecological), determining resource quality objectives and promoting pollution prevention, and through the provision of penalties for non-compliance.

The Water Services Act deals mainly with water services or potable (drinkable) water and sanitation services supplied by municipalities to households and other municipal water users. It contains rules about how municipalities should provide water supply and sanitation services. Within each municipal area, bylaws are developed which outline the water supply and effluent discharge regulations and tariffs for that area (see Section 3.2).

3.2.3 Wastewater policy

Under the National Water Act (Act 36 of 1998), norms and standards for the purification of wastewater or effluent prior to discharge have been set. These consist of general and special standards and set limits for aspects such as pH, temperature, chemical oxygen demand (COD), suspended solids, metals, etc. The test method that is to be used to determine these levels are also specified. Areas where the special standards apply are listed. Any industries or municipal or private wastewater treatment works discharging to river or sea must comply with these limits. In turn, the entity operating a wastewater treatment works must set limits for industries discharging to the works such that the DWS final discharge limits can be met. This is discussed in Section 3.2.

3.2.4 Environmental policy

The constitution of South Africa states that everyone has the right to an environment that is not harmful to his or her health or well-being (SAGovernment, 1996) and the right to have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development. Regulation that addresses these rights falls under the responsibility of the Department of Environmental Affairs (DEA).

Policy that is the most relevant to the soft drink sector is the National Environmental Management Act, 1998 (Act 107 of 1998) and in particular, the National Environmental Management: Waste Act, (Act 59 of 2008) and the National Environmental Management: Air Quality Act, 2004 (Act no. 39 of 2004). Broadly speaking, these Acts outline the requirements for the storage and handling of waste onsite (hazardous and non-hazardous), licensing requirements, the establishment of waste management plans, the setting of limits for air emissions, and the setting of penalties for offenses. Both these acts emphasise the need for the implementation of cleaner production and clean technologies to reduce the generation of pollution at source. These Acts have been amended more than once to update requirements as new technologies are developed and environmental protection has become more of a priority.

3.3 BY-LAWS AT LOCAL GOVERNMENT LEVEL

The handling and management of industrial effluent discharge creates huge potential problems for local authorities. The discharge of large volumes of industrial effluents into municipal sewerage systems, and in particular the discharge of effluents containing unwanted substances, could have a detrimental effect on the operation of the biological processes of the sewage treatment works. This could lead to the final treated wastewater discharged to the environment by the municipality meeting the required standards of the Water Act.

In an attempt to prevent industries in a particular municipal area from discharging effluent streams that may have a negative impact on public streams or the environment, local authorities set requirements to which industries must comply before they discharge to the municipal sewer. In accordance with these requirements, industries should apply for a special permit to discharge effluent to the wastewater treatment works. In the by-laws, limits are set for the quality of the effluent to be met, as well as limits on the discharge of any specific undesirable substances. In these permits for acceptance of industrial effluent by the municipality, the maximum volume that can be discharged is indicated, as well as any special measures relating to the quality of industrial effluent for the specific industry. By virtue of these by-laws and permit system, the local municipality has some control over the types and quantity of industrial effluent discharged into its sewage treatment works.

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

3.3.1 Industrial effluent tariffs

The calculation of industrial effluent tariffs varies significantly from one municipality to the next, depending on the cost recovery systems of the municipalities, types of industries discharging to the municipal sewer, and the wastewater treatment works that will have to treat the effluent.

3.3.1.1 Principles in respect of industrial effluent charges to recover costs

A rational tariff system should be used to calculate set out cost, rather than actual figures for cost recovery, these methods for calculation of costs should be used by the local municipality to recover the total annual cost for the sewage system and the wastewater treatment plant.

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

a. The 'polluter must pay' principle, contained in the Water Act, shall apply. Industries must pay for their portion of the transportation and treatment costs for effluent dumping them.

b. All sewerage rates are calculated according to the same rationale. Each local municipality should strive to get their tariff structure set in such a way that there is neither a loss nor a profit made on the wastewater treatment system. Unless there is a rational, fair method to estimate cost to allocate to private households, there is no way to ensure that industries on a volume basis are rated, not too much or too little paid.

c. As is the case with water and electricity tariffs, the main objectives of sewerage tariffs are firstly to recover the full costs of providing the service, and secondly to prevent unnecessary waste and pollution by letting, the user pays for such waste.

d. The rate charged for an industry must apply to the proportional costs for transport and Treatment of discharge from the relevant industry. These costs include amortization interest on capital works.

e. The transport costs for the effluent should not be based on geographical location, *i.e*. the same unit rates for transport should apply to all.

3.3.2 Examples of Bylaws and Effluent Tariffs

The Water Services Act sets out the regulatory framework for institutions tasked with the supply of water services and provide for different water services institutions to be established as follows:

- The water services authority (WSA) – i.e. the responsible municipality
- The water services provider (WSP) – whose role is to physically provide the water supply and sanitation services to consumers

Generally, within each municipality (the WSA) there is a department or unit that is responsible for the provision of water and the treatment of wastewater or the delivery of sanitation (the WSP).
The bylaws and tariffs for the eight metropolitan municipal areas are described in this section.

3.3.2.1 eThekwini Municipality

Important policy documents from the eThekwini Municipality include the Policies and Practices of the eThekwini Water and Sanitation Unit (EWS, 2013) which outline the policy related to provision of water and sanitation services, the Water Services Development Plan (EWS, 2011) and the Sewage Disposal Bylaws (EWS, 1999). The tariff schedule provides the related costs (EWS, 2014).

Any industry wishing to discharge to a wastewater treatment works must apply for a trade effluent permit. Requirements for this permit include the undertaking of a cleaner production assessment to identify measures to reduce the consumption of water and generation of wastewater at source. Trade effluent will not be accepted if it contains concentrations of substances above stated limits and separate limits are provided for sewerage works with a capacity both greater than, and less than, 25 ML/day. A third set of limits is applicable for industry discharging directly to one of the two sea outfalls (EWS, 2011).

Industrial, commercial and institutional customers are charged for the acceptance of sewage into the Municipal sewerage system by means of a volume based sewage disposal charge which replaced sewerage rates from 1 July 2010.

In addition to the above charge, Industries that are permitted to discharge trade effluent and with a COD greater than 360mg/l and SS greater than 9ml/l (pollution loading exceeding that of 'normal' domestic sewage) are charged for their high strength effluent at the rate calculated as given in Equation 1 (EWS, 1999).

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

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

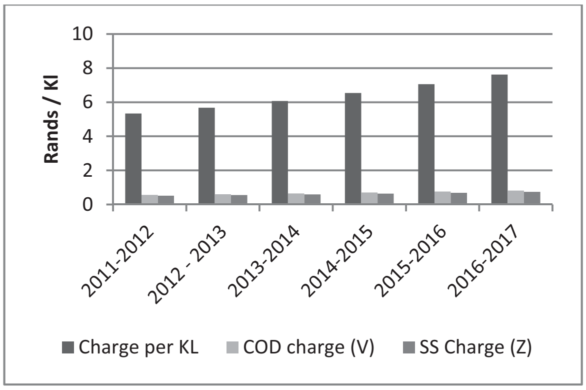
The volume of trade effluent discharged is determined by either a trade effluent meter, which is read every month and readings forwarded to the municipality, or through a water balance questionnaire which is filled in by the company. The water balance questionnaire subtracts the volume of domestic effluent, water used in product, in the process and loss due to evaporation from the incoming volume to give a percentage of trade effluent produced. Limits for effluent quality are set depending on the size of the receiving wastewater treatment works.

Data on basic unit cost for water and effluent and the values for V and Z are provided in Table 3.1.

Table 3.1: Basic unit costs for water and effluent in eThekwini Municipality (EWS, 2014)

Period	Effluent			Water (R/kL)
	(R/kL)	COD charge (V)	SS Charge (Z)	
2011-2012	5.34	0.57	0.52	12.8
2012-2013	5.68	0.6	0.56	14.79
2013-2014	6.07	0.65	0.59	16.63
2014-2015	6.54	0.71	0.64	18.78
2015-2016	7.06	0.76	0.69	20.84
2016-2017	7.62	0.82	0.74	23.14

The trends in water and effluent costs from 20211/2012 to 2015/2016 are shown in Figure 3.2.



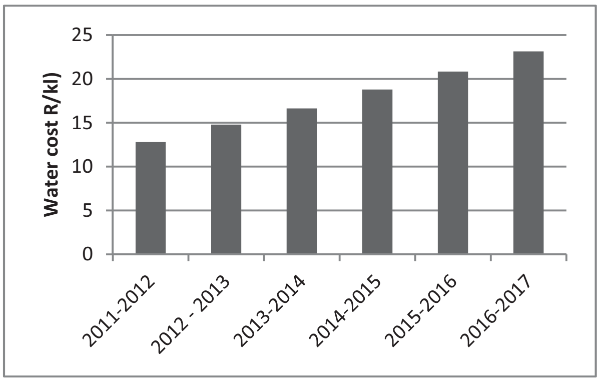


Figure 3.2: Trends in water and effluent costs in eThekwini Municipality (EWS, 2014)

3.3.2.2 City of Johannesburg

The Water Services Bylaws provide a description of the policy related to the provision of water and the discharge of industrial effluent. Limits are set for effluent quality with which industry must comply. An application for relaxation on these limits can be made, but this is dependent on a number of criteria being met including the use of best available technologies and the implementation of a waste minimisation programme (CoJ, 2008). Trade effluent tariffs are calculated based on the formula given in Equation 2.

$$\left[C + T\frac{COD}{700}\right] + \left[T\ \frac{(Metal-factor)}{factor}\right] + C(7 - pH) + (C + T)\frac{FOG-200}{200} \qquad [2]$$

Where: (CoJ, 2014)
C = 492.42 c/KL
T = 537.00 c/KL
COD = Chemical Oxygen Demand
FOG = Fats, Oils and Grease

- All concentrations of metals (mg/l) must be greater than the factor for the formula to apply
- pH term applies if pH is less than 4
- FOG term applies if FOG is greater than 200 mg/l

Metal	Factor	Metal	Factor	Metal	Factor	Metal	Factor
As	2.5	**Hg**	1	**Se**	2.5	**Cr**	20
Cd	2.5	**Mo**	5	**Zn**	20	**Cu**	20
Pb	10						

3.3.2.3 City of Tshwane

The relevant policies within the City of Tshwane are the Sanitation and Water Tariff Policies which outline the approach taken by the Municipality when setting water and sanitation charges. There are three different categories for industrial effluent charge (Tshwane, 2014):

1. **Normal conveyance and treatment cost**: Applies to effluent of the same quality as domestic wastewater discharged to sewer and is calculated by multiplying the combined unit conveyance and treatment cost by the volume discharged. Industrial consumers will be charged the tariff cost with a rebate of 10%.

2. **Extraordinary Treatment Cost:** Applies when the pollution loading exceeds that of normal wastewater and the cost is calculated as given in Equation 3:

$$\mathbf{Tc = Qc.t[0.6\,\frac{(CODc - CODd)}{CODd} + 0.25\,\frac{(Pc - Pd)}{Pd} + 0.15\,\frac{(Nc - Nd)}{Nd}} \qquad [3]$$

Where:
T_c = extraordinary cost to the consumer
Q_c = wastewater volume (KL)
t = unit treatment cost of wastewater (R/KL)
COD_c = total COD in mg/l of wastewater including biodegradable and non-biodegradable
COD_d = total COD of domestic wastewater in mg/l
P_c = orthophosphate concentration of wastewater in mg phosphate/l
P_d = orthophosphate concentration of domestic wastewater in mg phosphate/l
N_c = ammonia concentration of wastewater in mg nitrogen/l
N_d = ammonia concentration of domestic wastewater in mg nitrogen/l
2014 tariffs:
t = R 0.94 / KL
COD_d = 710 mg/l
P_d = 10 mg/l
N_d = 2 5 mg/l

3. **Non-compliance with By-Law limits**: where the limits are exceeded, the tariff given in Equation 4 will apply:

$T_C = Q / D.N\ [C_{AIP} – B_{LL}/W_{PL}]t_{NC}$ [4]

Where:
T_c = charge for non-compliance
Q = monthly volume in KL
D = working days in the month
N = number of days exceeding by-law
C_{AIP} = average concentration of parameter exceeding bylaw
B_{LL} = bylaw limit
W_{PL} = Water Affairs standard limitation on parameter exceeding bylaw
t_{NC} = tariff (R 0.65 / KL

Table 3.2: Basic unit costs for water and effluent in Tshwane (Tshwane, 2015)

	Water tariff (R/kL)			Effluent tariff (R/kL)		
	2012-2013	2013-2014	2014-2015	2012-2013	2013-2014	2014-2015
0-1 0 000 kℓ	11.89	13.08	14.39			
10 001-100 000 kℓ	11.29	12.42	13.66			
More than 100 000 kℓ	10.52	11.57	12.73			
Charged at 60% of incoming water				4.66	5.13	5.64

3.3.2.4 City of Cape Town

The City of Cape Town has bylaws relating to Wastewater and Industrial Effluent (CoCT, 2014) which sets out the requirements and limits for industrial effluent discharge, and a Treated Effluent Bylaw (CoCT, 2010) which outlines the permitted use of treated effluent (e.g. for irrigation, etc.).

Limits are set for effluent discharge with respect to general pollution loads such as COD and electrical conductivity, as well as for chemical substances, heavy metals, and inorganic content (Schedule 1 of the Wastewater and Industrial Effluent). Failure to comply with these limits results in the application of a surcharge factor (CoCT, 2013).

3.3.3 Summary of industrial effluent standards of some of the major municipalities

Table 3.3 summarises the industrial effluent standards of major municipalities for some of the most common water quality parameters regulated for in effluents from industries.

Table 3.3: Effluent standards of major municipalities for some of the most common water quality parameters regulated for in effluents from industries

Local authority		pH	COD (mg/L)	Ortho-phosphate (mg/L as P)	TSS (mg/L)	EC (mS/m)	Sulphate (mg/L as SO_4)	FOG (mg/L)
City of Tshwane		6-10	5000	10	2000	300	1800	500
City of Cape Town		5.5-12	5000	25	1000	500	1500	400
eThekwini	WWTW < 25 ML/d	6.5-10	Charge		1000	400	250	250
	WWTW > 25 ML/d	6-10	Charge		2000	-	250	250
Ekurhuleni		6-10	5000	50	1000	500	1800	500
Msundusi		6.5-9.5	-	20	400	400	250	2250
City of Johannesburg						500	250	
Mossel Bay		6-11	4000	-	1000	500	500	400
George		6-10	3000	-	1000	250	500	400

CHAPTER 4: WATER USE AND MANAGEMENT

4.1 WATER USE IN THE LAUNDRY INDUSTRY

Since the literature review did not provide sufficient information regarding the water and wastewater management practices of the South African laundry industry, it was necessary to conduct surveys to attain this information. The "SA Yellow Pages" (www.sayellow.com) and "Brabys Online Business Directory" (www.brabys.co.za) were used to conduct an internet search of laundry businesses in South Africa. Laundromats were included in the search for commercial laundries. A total of 668 commercial laundries were found and used to populate a Microsoft Excel database. The results are summarised in Figure 4.1.

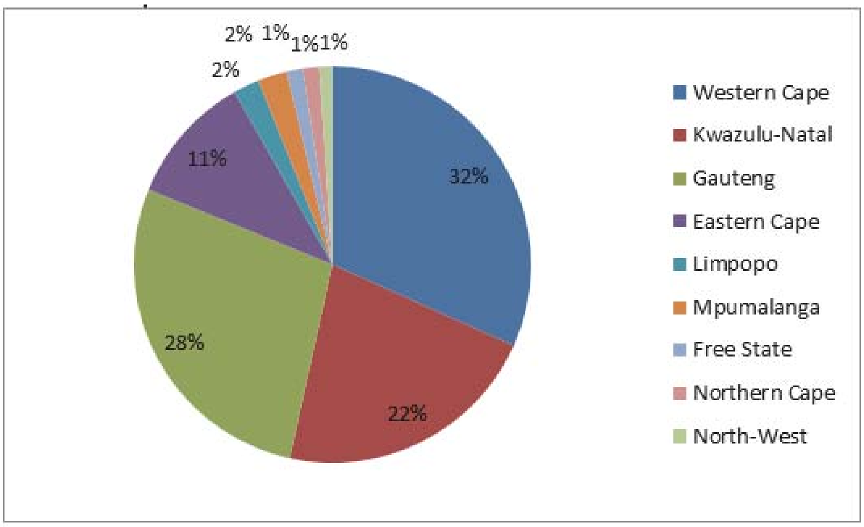


Figure 4.1: Distribution of laundries in the different provinces

The database fields are based on the aims of the NATSURV document. These fields include size classification, washing loads (kg/day), type of washing machine used, total water intake (kL/day), SWI (L/kg), effluent discharged (kL/day), COD, TSS, TDS (EC), phosphate, calcium, magnesium, pH, energy usage and existing recycle treatments.

Telephonic surveys were conducted with laundries included in the database. More than 20% of the contact details provided by "SA Yellow Pages" (www.sayellow.com) and "Brabys Online Business Directory" (www.brabys.co.za) were invalid or did not exist anymore. Of the 182 laundry companies who answered only 55 responded to respond to the telephonic questionnaire.

4.1.1 Water use and management of laundries visited

Laundries representative of the small, medium and large laundry sectors were selected for site visits. Information obtained during visits to medium-sized to large laundries are summarised in Table 4.1, while Table 4.2 provides information on the small laundries that were visited.

Table 4.1: Water management information of medium-sized to large laundries that were visited.

Laundry identification	A1	A2	A3	A4	A5	A6
Types of laundry processed	Work wear and linens[1].	Linens: 60% Work wear: 40% More than 300,000 items per month	Linens and work wear.	Work wear and linens.	Linens (mostly sheets and table cloths).	Work wear and linens.
Client base	Factories; hospitality industry; restaurants; health care.	Hospitality industry the largest client base. Currently diversifying to include further clients.	Hospitality industry (linens and uniforms), health care (hospitals). Factories.	Factories (various types). They are a large service provider for industry and work on a national base.	Hospitality industry (restaurants, hotels); guest houses; schools and dormitories.	Factories (uniforms); hospitality industry; hospitals; schools.
Rental arrangements	Yes, on a large scale for work wear. Linen is non-rental.		Only for factories (uniforms).	Yes, for some of industry types uniforms.	No.	Yes, but on a limited scale.
Washing processes and machines	Tunnel washers; traditional washer-extractors; pulse-flow continuous washers (new technology)	Washer-extractor machines only. Total of 22 machines (does 7.5-110 kg each). One main wash, three rinses.	Two batch loaders. A number of front loading washing machines.	20 large front loader machines.	Front loaders (some of the machines are very old).	Front loaders only.
Water source	Municipal water and borehole water.	Municipal.	Borehole water only. Municipality installed flow meters on the boreholes.	Municipal water.	Borehole water.	Municipal water.

[1] Collective term for bed, bath, table and kitchen textiles.

Laundry identification	A1	A2	A3	A4	A5	A6
Water intake volumes	Washer-extractor: 25-30 L/kg Tunnel washers: 8-10 L/kg Garments: 12-14 L/kg Pulse-flow washers: Down to 2 L/kg	High (figures will be supplied). Water bill: R70000/m	Batch loaders: 6-8 L/kg Front loader machines: 25 L/kg	Front loaders: 22-30 L/kg	Medium sized laundry. Front loaders typically use around 30 L/kg, but there are a lot of leakages that were observed, hence the water use will be in excess of this figure.	To be verified.
Water quality	Municipal water: high pH a concern. Reduce the incoming water pH to 5.5-6.5 for the rinsing processes. Borehole water: hard water, they have a softening plant.	Has a treatment plant for conditioning of the incoming water. Ion-exchange system for softening of the incoming water.	Do not have specific problems with the quality of the borehole water.	No specific problems with the incoming water quality.	No problems with the borehole water quality	They do not have specific problems with the quality of the incoming water.
WQ Monitoring by the laundry	Daily, for pH, TDS, Fe and harness	Daily for pH.	pH only. The chemicals supplier does water quality testing on a weekly basis.	Test for pH, EC and occasionally for hardness.	Occasionally tested by the chemical suppliers.	Measure pH and EC on a regular basis.
Water conservation measures	Looking at recycling systems. Investigating new washing technology.	Discussions with consultants who claim that water intake savings of up to 80% is possible.	Yes (more information to be obtained).	They are investigating extension to the recycling systems to reduce the fresh water intake	Do some recycling, but no plans to extend this at present. Rectifying the leakages will reduce the borehole water consumption.	Want to recycle the rinse water for use elsewhere in the laundry.

Table 4.2: Water management information of medium-sized to large laundries that were visited.

Laundry identification	A7	A8	A9	A10	A11	A12
Types of laundry processed	Domestic (private clients)	Clothing, sheets, duvets	Clothing	Clothing	Printing wipers	Various domestic
Client base	Private clients	Private clients and businesses	Private clients	Private clients	Private clients	Private clients
Rental arrangements	No	No	No	No	No	No
Washing processes and machines	14 top loader washing machines and 12 driers. Does up to 50 kg of washing per day.	5 top loaders and 8 driers (Note: top loaders typically use 40-45 L/kg).	2 front loaders and 1 top loader. Can do about 13 kg of washing each	6 top loaders	2 large tumble washers and 1 small tumble washers (± 300 kg, 200 kg and 150 kg machines)	2 top loaders and 2 front loaders
Water source	Municipal	Municipal	Municipal	Municipal	Municipal	Municipal
Water intake volumes	Obtain from municipality	Obtain from municipality	Obtain from municipality	Obtain from municipality	Obtain from municipality	Obtain from municipality
Water quality	No problems	No problems	No problems	No problems	No problems	No problems
WQ Monitoring by the laundry	Do not do any tests	Do not do any tests	Do not do any tests	Do not do any tests	Do not do any tests	Do not do any tests
Water conservation measures	None	None	None	None	None	None

4.2 GUIDELINES ON WATER USE IN THE INDUSTRY

Water usage in laundries can be reduced by implementing the following practices:

- Optimisation of water recycle systems to make best use of higher quality waters.
- Treatment of rinse waters to render them of higher quality and therefore of greater potential for reuse.
- Design of new equipment (both washers and rinsers) to ensure efficient water use
- Optimisation of the operation of boilers by minimizing unnecessary blow-down (water intentionally wasted from a boiler to avoid concentration of impurities during continuing evaporation of steam).
- Installation of water meters at all key areas of the laundry process line.
- Monitoring of and taking action on water meter figures.
- Ensuring that staff is trained to appreciate the need for water conservation in the laundry.
- Ensure that equipment automatically switches off when loads of washing are being transferred from one stage to another.
- Equip floor-washing hoses with automatic shut-off mechanisms.
- Maintain equipment in good order to minimize leaks.

CHAPTER 5: WASTEWATER GENERATION AND MANAGEMENT

5.1 WASTEWATER GENERATED IN THE LAUNDRY INDUSTRY

The quality of wastewater discharged by laundries varies according to its origin. Indicative of this are COD values, which can be up to 20 000 mg/L in laundries, up to 1 200 mg/L in hospitals and up to 2 500 mg/L in households (Gosolits *et al*., 1999). Laundries are also commonly associated with elevated levels of sodium, phosphate, boron, surfactants, ammonia, nitrogen, SS and turbidity (Ahmad & El-Dessouky, 2008).

Wastewater from laundries is generally treated with one or more of the following methods (Fijan *et al*., 2008):

- Coagulation and flocculation (Removes SS and colloids)
- Activated carbon filtration (Removes organic pollutants)
- Oxidation (Ozone, UV, chlorination and peroxides)
- Biological methods (Degrades organic material and nutrients)
- Ion exchange technology (Reduce water hardness)
- Membrane filtration (Removes small particles and colloidal material)
- Electro-chemical methods (e.g. electro-coagulation and electro-flotation)

The methods laundries use to treat their wastewater usually depend on the type of textiles they launder, their capacity and financial capability. Conventional treatment methods are usually preferred by laundries, primarily due to financial constraints, but research has been done on more modern applications, *i.e.* membrane filtration and electro-chemical methods. These methods are very expensive and require considerable maintenance (Sostar-Turk *et al*., 2005; Fijan *et al*., 2008).

An example of a modern wastewater recycling approach is illustrated in Figure 5.1.

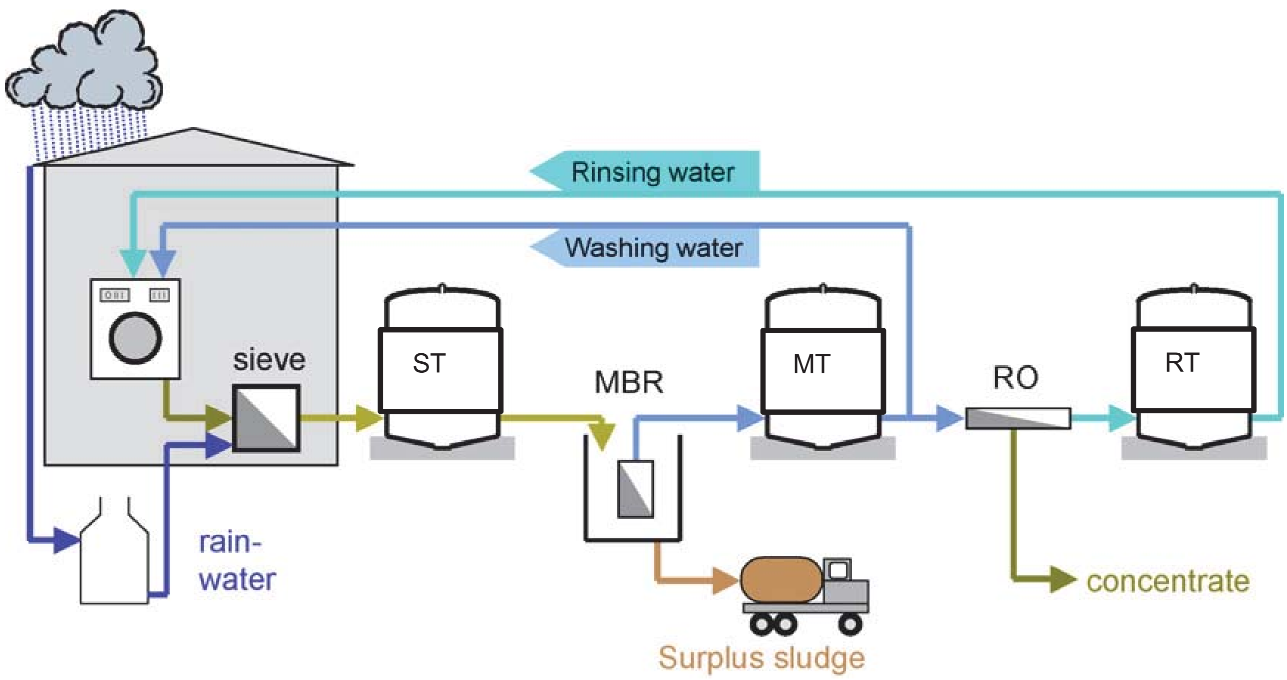


Figure 5.1: An example of a modern approach to wastewater recycling at a large commercial laundry (Hoinkis & Panten, 2008).

For the example in Figure 5.1, wastewater and harvested rain-water is first subjected to coarse screening using a vibrating sieve, after which it is stored in a storage tank (ST). The wastewater is then exposed to a membrane bioreactor (MBR) where air is injected to drive the biological treatment. After microfiltration the water is stored in another tank (MT). At this stage the turbidity and microbial load is extremely reduced, allowing for its application as wash water in the laundering process. The permeate from MT can be further treated with chlorine dioxide and reverse osmosis (RO), and then stored in another tank (RT), after which it can be used as rinsing water. The concentrate after RO is sent to a municipal treatment plant, and the surplus sludge is collected by commercial waste management companies

Membrane filtration (Figure 5.2) is more advantageous when compared to conventional treatment methods considering their fulfilment of higher standards, reduced environmental impact and possible application as mobile treatment units (Sostar-Turk *et al*., 2005). Studies have indicated that membrane filtration gives such good quality permeate that laundries are enabled to re-use their wastewater for laundering purposes (Ahn & Song, 1990; Hoinkis & Panten, 2008). Pre-filtration (particle filtration) is essential to ensure that subsequent membranes used do not get blocked. Pre-filtration usually entails using equipment relying on pressure-, gravity- or centrifugal filtration. Suitable laundering chemicals must be used to protect membranes from degradation by acids, alkalines, solvents and microbes. Anti-scalants must also be used to protect membranes from deposit build-up by bio-fouling, colloidal fouling and scaling by carbonates and sulphates. Ceramic UF membranes are used since they are more robust. It is important to know that better permeate quality requires higher filtration costs. RO membranes give the highest permeate quality by removing the smallest particles, such as salts, but they are very expensive (*Training Modules on the Sustainability of Industrial Laundering Processes, n.d.*).

Electro-chemical methods are usually used as a more efficient replacement for traditional coagulation and flotation methods. Conventional methods often fail in removing high contents of SS, oil, surfactants, phosphates, dyes, heavy metals and phenols, whilst electro-chemical methods (with additional simultaneous degradation and removal mechanisms) easily deal with these potential environmental problems. They have also attracted attention due to their safety and environmentally friendly nature (Fijan *et al*., 2008).

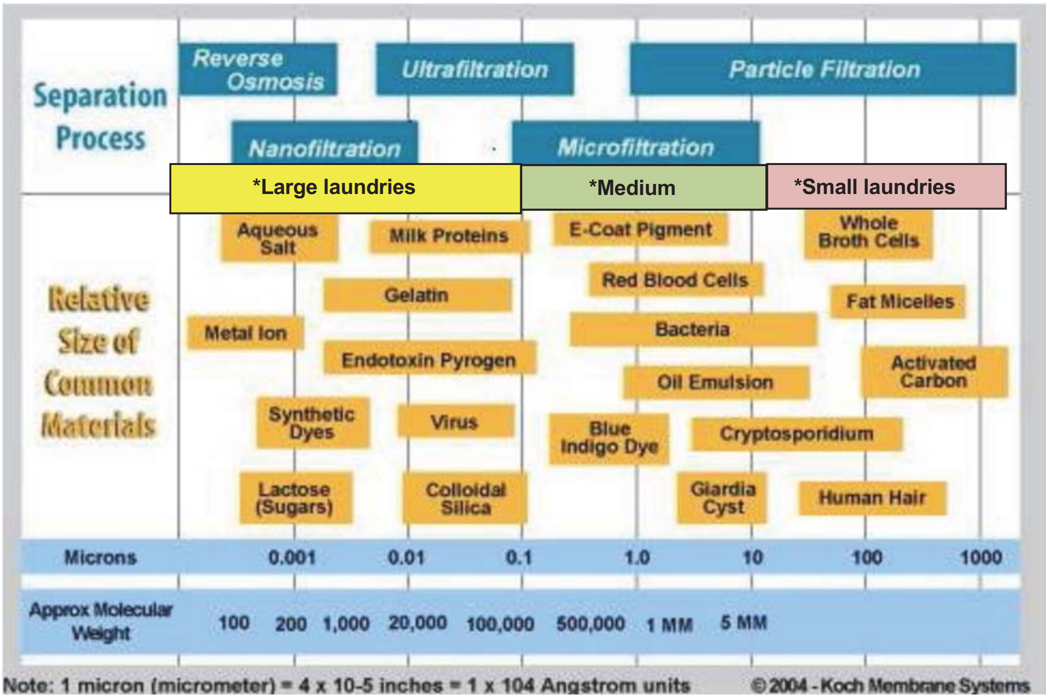


Figure 5.2: Range of different membrane filtration applications (Koch Membrane Systems, 2004)

e. Other options mentioned in literature which can be considered

Other options to consider include:

- Since coagulation and flocculation are ineffective at removing colour from laundry wastewater sufficiently, they can be followed up by using granular activated carbon for the adsorption of colour particles (Sostar-Turk *et al*., 2005).
- Use environmentally friendly, biologically degradable laundering products and avoid overdosing since this can negatively impact wastewater quality (Fijan *et al*., 2008).

- Layered sand and gravel filters can be used as a cheap wastewater treatment method – One study even claimed that the treated wastewater can be re-used as rinse water for very dirty textiles (Ahmad & El-Dessouky, 2008)
- Chemical dosage sensors can be installed to prevent unnecessary wastewater burdens resulting from over-dosing (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

5.2 LAUNDRY INFORMATION OBTAINED DURING SITE VISITS

During the site visits to laundries around the country, information was obtained on pollutants on the garments, chemicals used in the washing processes, effluent treatment processes (if any), recycling practices and sampling programmes. The information is summarised in Table 5.1 and Table 5.2.

Table 5.1: Details of medium-sized to large laundries visited and samples taken of effluent streams

Laundry identification	A1	A2	A3	A4	A5	A6
Chemicals used in the washing processes	Use standard detergents. They are continuously investigating new 'green' chemicals, and are also looking at enzyme-active detergents	Standard detergents used in the laundry industry.	Low surfactant detergents (LSD). Sodium meta-silicate.	Still use phosphate-based detergents, because it produces the best results. Try to wash at lower temperatures	Standard laundry detergents and chemicals.	Sulfonates and alkalis. They produce their own chemicals on site, and also supplies to other smaller laundries.
Pollutants from garments washed	Canning industry; pharmaceuticals; paint shops; hospital garments with pathogens (wash at > 80°C and use paracetic acid)	Mostly hospitality industry, i.e. soiled garments, organics, fats and grease.	Organics, fats and grease as well as some inorganics from factories. Biological from the health-care industry.	Various, including inorganic pollutants from factories using salts, metals, alkalis, etc.	Mostly organics from soiled uniforms and linens.	Both organic and inorganic. No toxic pollutants treated.
Existing treatment processes	They have basic treatment processes such as screening and pH correction. Large water treatment company is currently investigating their effluent treatment requirements	No treatment systems at present, but have commissioned consulting engineers to investigate feasibility of different treatment options.	None	Only dosing systems for pH adjustment, and in-line filters (strainers).	None	Strainers
Internal wastewater quality management	Use Google Drive to network all data	None	Chemical supplier does occasionally	Does basic tests such as pH.	None	None
Recycling	Wants to do greywater recycling, and looking at treatment processes to use for this purpose	Looking at treatment systems that may recover up to 80% of the effluent currently discharged to sewer	Do not currently do any recycling.	Recycle some of the rinse water. Wants to expand this in future.	Recycling some water to the boilers.	Do not currently recycle their rinse water streams.
Sampling by municipality	Municipality takes samples monthly. Laundry do not get results from the tests, only an account. Feels the type and location of sampling is not fair	Municipality does not take samples.	Done on a monthly basis. The municipality does not have any problems with the water quality, mostly assessing the volume of water used.	Sampling done on a monthly basis by the municipality.	No sampling is done by the municipality.	The municipality samples on a monthly basis.

Table 5.2: Details of small laundries visited and samples taken of effluent streams

Laundry identification	A7	A8	A9	A10	A11	A12
Chemicals used in the washing processes	Soap powder, bright wash and staysoft	Industrial soap, softener and bleach	Soap powder and softener	Soap powder, bright wash and softener	NP9 Tergitol, sodium carbonate light, sodium metasilicate pentahydrate and sodium tripoly-phosphate technical-C	Soap powder and stasoft
Pollutants from garments washed	Soil from clothing (domestic laundry)	Bedding and linen from guest houses mainly	Soil from clothing (domestic laundry)	Soil from clothing (domestic laundry)	Printing wipers and some clothing	Soil from clothing (domestic laundry)
Existing treatment processes	None	None	None	None	None	None
Internal wastewater quality management	None	None	None	None	None	None
Recycling	None	None	None	None	None	None
Sampling by municipality	None	None	None	None	Every 6 weeks	None

5.3 SAMPLING OF LAUNDRY EFFLUENT STREAMS TO ESTABLISH WASTEWATER QUALITY RANGES

Samples were taken of the wastewater streams discharged at a number of laundries in the Western Cape and Eastern Cape, and analysed for the main water quality parameters used for regulating the discharge of the final effluent to municipal sewer. The results are shown in Table 5.3.

Table 5.3: Chemical analysis of effluent samples taken at small to medium sized laundries in the Western Cape and in Eastern Cape

Laundry identification	COD (mg/L)	TP (mg/L as P)	TKN (mg/L as N)	pH	Absorbance (600 nm)
WC1	1298	0,8	3,7	10,6	0,151
WC2	1410	0,6	4,8	10,2	0,236
WC3	1232	1,0	4,3	10,5	0,105
WC4	1071	3,8	3,2	10,4	0,217
WC5	18350	1,1	80,0	8,5	0,162
WC6	1250	0,5	4,2	9,7	0,133
WC7	660	0,8	3,2	7,4	0,127
EC1	956	1,3	7,7	10,4	0,059

At two of the large laundries in the Western Cape, samples were also taken of the various wastewater streams emanating after the sequential washing and rinsing cycles that are used. The purpose of this sampling program was to show the variability of the quality of the wastewater during the different washing and rinsing cycles employed in the laundering processes. Wastewater quality data of this nature would be required by laundries wishing to embark on a water recycling program within the laundry to reduce the fresh water intake. The results of these sampling programs are shown in Table 5.4, Table 5.5 and Table 5.6.

Table 5.4: Chemical analysis of effluent samples taken of different discharge streams during the washing and rinsing cycles in a large laundry in the Western Cape

Sample	Temp. (C°)	pH	EC (mS/m)	COD (mg/L)	PO_4 (mg/L)	P (mg/L)	SS (mg/L)	Total Solids (mg/L)
Main Wash (WM 12)	41	9.1	277	555	243	79.5	43	184.56
First Rinse (WM 12)	26.5	8.44	171	580	46.6	15.2	73	6.17
Second Rinse (WM12)	21	8.48	153	585	20.2	6.61	55	5.16
Pre Wash (WM6)	19	7.58	161	770	6	1.96	16	8.79
Main wash (WM 6)	54	9.69	416	885	663	217	207	31.77
First rinse (WM 6)	30	9.01	168	690	61.4	20.1	34	7.19
Second rinse (WM 6)	22	8.67	147	775	12	3.92	26	4.52
Final Effluent	24	8.66	208	845	113	36.8	80	11.11
Main wash (WM 9)	45	11	519	6160	419	137	215	66.05
First rinse (WM 6)	30	10	216	870	92.8	30.3	132	15.77
Second rinse (WM 6)	22	9.38	163	565	31.7	10.4	323	9.91
Final Effluent	33	9.21	215	590	140	45.8	107	12.81

Table 5.5: Chemical analysis of effluent samples taken of different discharge streams during the washing and rinsing cycles in a second large laundry in the Western Cape

Sample	pH	EC (mS/m)	Ca (mg/L)	Mg (mg/L)	COD (mg/L)	PO_4 (mg/L)	P (mg/L)	SS (mg/L)	Total Solids (mg/L)
Main Wash	7.22	29	12.09	3.86	590	0.03	0.01	67	0.42
Rinse 1	7.13	20	12.55	3.25	630	0	0	65	0.32
Rinse 2	7.02	22	13.23	3.17	595	0.15	0.05	85	0.43
Rinse 3	7.17	18	13.79	3.15	780	0.03	0.01	53	0.53
Final Effluent	7	22	13.21	3.14	590	0	0	23	0.32

Table 5.6: Chemical analysis of effluent samples taken of different discharge streams during the washing and rinsing cycles in a medium-sized laundry in the Southern Cape

Sample	pH	Turbidity (NTU)	TSS (mg/L)	EC (mS/m)	Sulphate (mg/L as SO_4)	Orthophosphate (mg/L as P)	COD (mg/l)
Main wash 1	9.03	34.7	36	82	116	4.6	211
Rinse 1	9.35	22.8	32	42	3	2.1	222
Main wash 2	6.74	43.7	24	98	65	6.6	333
Rinse 2	7.96	17.9	18	36	4	2.3	88

5.4 WASTEWATER QUALITY DATA OBTAINED FROM MUNICIPALITIES

Results of monthly sampling and chemical analysis of laundry wastewater streams discharged to municipal sewer systems were obtained from the metropolitan municipalities in Durban (eThekwini), Pretoria (Tshwane) and Cape Town (City of Cape Town).

Table 5.7 to Table 5.10 provide examples of monthly water intake volumes and average monthly effluent quality of laundries that are regulated by eThekwini Municipality (Table 5.7, Table 5.8 and Table 5.9) and the City of Cape Town (Table 5.10).

Table 5.7: Laundry wastewater quality averages monitored over a period of 12 months indicating typical quality discharged to municipal sewer: eThekwini Southern Region, 2014

Southern Region: Jan 2014-Dec 2014					
Laundry identification	Water intake (kL/month)	COD (mg/L)	EC (mS/m)	pH	Settl.Solids (mL/L)
South 1	184	91	52	8,9	0
South 2	1109	644	211	7,3	2,6
South 3	723	496	220	9,4	1,5
South 4	3426	364	46.8	8,9	0,3

Table 5.8: Laundry wastewater quality averages monitored over a period of 12 months indicating typical quality discharged to municipal sewer: eThekwini Northern Region, 2013

Northern Region: Jan 2013-Dec 2013					
Laundry identification	Water intake (kL/month)	COD (mg/L)	EC (mS/m)	pH	Settl.Solids (mL/L)
North 1	421	337	319	10,2	0
North 2	8117	157	59	9,3	0,1
North 3	15204	533	148	9,8	1,7
North 4	759	217	33	7,4	1,1
North 5	<100				
North 6	<100				
North 7	<100				
North 8	<100				
North 9	<100				
North 10	<100				
North 11	<100				
North 12	<100				

Table 5.9: Laundry wastewater quality averages monitored over a period of 12 months indicating typical quality discharged to municipal sewer: eThekwini Northern Region, 2014

Northern Region: Jan 2014-Dec 2014					
Laundry identification	Water intake (kL/month)	COD (mg/L)	EC (mS/m)	pH	Settl.Solids (mL/L)
North 1	421	333	302	10	0
North 2	8117	283	92	9,9	0
North 3	15204	648	132	8	0,5
North 4	759	467	75	8,2	1,3
North 5	<100				
North 6	<100				
North 7	<100				
North 8	<100				
North 9	<100				
North 10	<100				
North 11	<100				
North 12	<100				

Table 5.10: City of Cape Town municipal samples showing variability of the wastewater quality

Laundry	Sampled Date	COD (mg/L)	Conductivity (mS/m)	pH
CT3	15/04/2014	20	16	8
	06/05/2014	85	26	9.6
	12/05/2014	319	19	9.7
	20/05/2014	297	88	10.4
	10/04/2015	771	285	10.9
	10/06/2015	20	19	9.2
	23/06/2015	1478	426	11
	09/07/2015	423	132	10.6
CT4	23/03/2015	609	542	10.5
CT5	28/01/2015	185	41	10.3
	05/02/2015	202	56	10.4
	11/02/2015	240	186	2.4
	18/02/2015	80	24	10
CT6	11/03/2015	215	108	10.6
	22/04/2015	110	52	10.3
	23/04/2015	269	23	9.5
CT7	29/08/2013	186	163	11
	08/11/2013	116	96	10.7
	12/12/2013	257	75	10.6
	17/02/2014	269	148	10.7
	31/03/2014	168	163	10.7
	06/05/2014	374	191	11.1
	03/06/2014	376	250	11.6
	08/07/2014	275	186	10.9
	08/09/2014	478	157	10.8
	14/10/2014	728	255	11.1
	19/11/2014	537	277	11
	05/02/2015	301	191	10.8
	17/03/2015	511	303	11
	21/04/2015	363	162	10.9
	02/06/2015	312	139	11.1
	21/07/2015	399	239	11.2
	27/08/2015	20	12	8.7
CT8	13/08/2014	743	218	10.9
	08/10/2014	952	312	10.9
	18/06/2015	431	143	10.6

CHAPTER 6: ENERGY USE AND MANAGEMENT

6.1 ENERGY USE IN THE LAUNDRY INDUSTRY

Costs relating to energy are generally regarded as the second highest expenditure of commercial laundries (Seneviratne, 2007). Besides the electricity required to operate the machinery, the major consumer of energy in commercial laundries is the drying and heating processes. Steam-heated drying equipment consumes large amounts of energy, and the general consensus is that gas-heated drying equipment will be a more economical option. Steam requires a lot of water and energy. The drying process, which involves removing residual water from laundered textiles, consists of a mechanical dewatering step and a thermal drying step. Mechanical dewatering (via pressing or spinning) is a relatively fast and low level energy consuming step. Thermal drying is required thereafter to remove the remaining moisture from textiles and it is a relatively slow and high level energy consuming step. Besides optimisation of the mechanical dewatering step, the main treatment options for reducing energy consumption in the drying process are related to the thermal drying step (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

Thermal drying involves the removal of excess water by evaporation. The heat required for this is generated by steam, gas or electrical heating. Thermal drying is conducted in a dryer, garment finisher or a flatwork ironer. It is advisable to uniformly distribute heat throughout the drying chamber and recirculate this hot air internally, which can amount to about 30% savings in energy. Energy consumption in the thermal drying process can also be optimised with the following measures (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.):

- The application of gas-heating equipment rather than steam-heating equipment.
- Not over-loading the machine to ensure efficient thermal drying.
- Determining the correct end-point of the thermal drying process (over-drying uses excessive energy and can damage the textiles, whilst textiles will be overly wet when thermal drying is too short).

It is clear that heat is essential in the laundering process. It is required for the optimal function of chemicals, disinfection and solubilising contaminants (such as fats). High temperatures are ultimately associated with increased energy requirements (Seneviratne, 2007). It is therefore possible to consider low temperature laundering (cold-wash) procedures in order to reduce energy usage. This requires alternative chemical products. It is also possible that stain removal and disinfection will be negatively affected upon implementing cold-washing processes (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

Heat recovery usually involves the application of heat-exchangers. Before going to the drain, hot laundering water passes this heat exchanger for cool-down and in turn heats up counter-flowing incoming fresh water (Fijan *et al*., 2008). As much as 60% of the heat can be recovered in this manner (Seneviratne, 2007) and fresh water temperatures can be raised by up to 30°C (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.). Heat exchangers therefore have several advantages (Fijan *et al*., 2008):

- Lower wastewater temperatures will comply with relevant regulations.
- Rinsing is enhanced when rinsing water is at higher temperatures.
- Drying times are shortened due to lower residual moisture.
- Finishing processes will use less energy since rinsing is more efficient.

There are also several other measures that can be taken to reduce total energy usage. Over-loading can result in extra wash cycles, which wastes energy. The weight of textiles must therefore be checked before loading the washing machine. Using excessive amounts of water results in extra energy costs since more heat is required. Monitoring water usage is therefore required to optimise energy consumption. When steam-heating equipment is used, it is advisable to use a more economically efficient pressure (e.g. 2-4 bars are economically more efficient than 10-16 bars) (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

6.2 SPECIFIC ENERGY USE PER PROCESS OR TECHNOLOGY

Very little information could be obtained from laundries on their energy usage. The only figures that they are aware of related to the energy usage are those of electricity consumption as provided in the municipal water and electricity bills. Most of the laundries were not willing to allow the project team to work through their monthly municipal accounts to obtain and summarise this information.

It was therefore decided to attempt obtaining this information from a number of municipalities where medium to large laundries are in operation. Again, on request this data was not supplied by the majority of the municipalities. It is suggested that in related projects focusing on energy use in industries, this route be followed to characterise the electricity consumption of those industries studied (i.e. by including a number of larger municipalities onto the project team and performing a detailed data assessment and processing within the industries and the municipalities' financial departments).

CHAPTER 7: WATER USE: BEST PRACTICE

7.1 WATER CONSERVATION AND DEMAND MANAGEMENT

The application of water-conservation techniques should enable commercial laundries to have SWIs of 12-15 L/kg and 1.5-4.5 L/kg for WEs and CBWs, respectively (Brown, 2009). Water consumption must be accurately monitored and ultimately compared with theoretical, programmed water use. When the comparison reveals that more water is used than required, it will then be possible to start identifying causes. Options for reducing the total water usage of a commercial laundry include the following (Seneviratne, 2007):

- Repair leaking drain valves and hoses – a 3% reduction in water usage is realisable.
- Excessive steam generation must be inspected.
- Computerised programming relating to water usage during laundering process must be optimised (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).
- Chemical dosage must be monitored – too much relates to more rinsing water required, whilst too little leads to insufficient results which require repeated washing.
- Whilst incorporated in most CBWs, the re-use of rinsing water for pre- and main wash water should be considered in WEs, with up to 30% savings on laundering water possible.
- Washing machines should not be over-loaded, since insufficient results will require repeated washing.
- Washing machines should not be under-loaded, since this can result in wastage of water.
- The residual water extracted by mechanical pressing can be collected and re-used in the washing stage.
- A cascade system – using laundering water from high-on-quality demand textiles (e.g. hotel linen) on low-on-quality demand textiles (e.g. garage work-wear) – can reduce total water intake (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).
- The use of ozone for disinfection can reduce the amount of chemicals and rinse cycles used, which can lead to total laundering water savings of up to 20%.
- Water efficient installations in amenities blocks (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).
- When buying washing machines, WEs and CBWs with internal recycling measures should be considered (Training Modules on the Sustainability of Industrial Laundering Processes, n.d.).

There are also several considerations that need to be taken into account when aiming to re-use WE rinse water. These include the following (Fijan *et al*., 2008):

- WEs must be fitted with a second drain valve (for recycling purposes) and another inlet to receive the recycled water.
- Storage demands for installing tanks, pumps and valves.
- The alternation between white and coloured textiles.
- This technology has high initial costs and long payback periods.
- Re-use technology might not be required if fresh water and wastewater treatment is a manageable expenditure.
- If the incoming water or textiles contain hazardous substances then re-use might be a risky option.

Laundry wastewater can, instead of going to the drain, be treated and used again only for the washing stages of the laundering process. This usually entails allowing the wastewater to collect in a collecting pit, after which it is sent to an equalisation tank. Particulate matter is then removed using a lint shaker. The water is then pumped to a clarifier or a dissolved air flotation unit in which coagulants and chemicals is injected. FOGs are broken down and SS are trapped. The water, still containing dissolved solids, is then sent to a storage tank. This water is then only re-used for hot water applications (*i.e.* washing stages). If the dissolved solids are excessive then they can be diluted with fresh water. When additionally aiming to re-use this water for rinsing stages as well, it is necessary to remove total dissolved solids. This requires pre-treatment (e.g. micro- or ultra-filtration) prior to the application of nano-filtration and reverse osmosis (RO) membranes. This option generally yields up to 85% of water recovered (Seneviratne, 2007). This is only an example, and all treatment options should be considered first before implementation.

7.2 WATER USE TARGETS

Follow-up contacts were made with municipalities to obtain information on laundries within their area of jurisdiction, their metered water usage and electricity consumption, effluent quality (where available) and key water quality parameters measured by the municipality.

The following questions were supplied, and indicated by the relevant numbers in the table:

- Question1. Can you provide us with a list of laundries (excluding dry) in your jurisdiction? (Names and size)
- Question 2: From the list provided, can you highlight the name of those laundries where monthly sampling of effluent is performed?
- Question 3: What are the key pollutants monitored in the effluent?
- Question 4: Can you provide effluent quality data for the past two years if available?
- Question 5: Can you provide information pertaining to the laundry activities:
- Question 5.1: Volume of municipal water used (monthly)
- Question 5.2: Volume of ground water abstracted monthly (if applicable)
- Question 5.3: Monthly energy use

The results of this survey are shown in Table 7.1.

Table 7.1: Information supplied by municipalities on water and wastewater management of laundries within their area of jurisdiction

Institution	Questions and response							
	Q1	Q2	Q3	Q4	Q5	Q5.1	Q5.2	Q5.3
Municipality or Water Services Authority 1	Provincial laundry (closed)	George provincial laundry	pH, EC, COD, SS, Chloride and alkalinity	Yes July 2015 pH: 10.58 COD: 321 EC: 92.9 SS: Alkalinity: 303 Chloride: 135 SS: 28 TDS: 587 (see details in attachment)	Yes, for the year 2014 only	Oct: 261 KL Sept: 990.9 KL Aug: 739.8 KL Jul: 779.84 KL Jun: 747.9 KL May: 747 KL April: 665 KL Mar: 710.1 KL	Not applicable	Not applicable
Municipality or Water Services Authority 2	There are five laundries that are monitored	All of them but on random basis	pH, COD, alkalinity and SS	Not available but can recall the most recent range July-Nov 2015 pH 9-11.4 COD: 234-342 Alkalinity 124-300; SS: 12-32	Yes if available	Depending on consumption, the average is about 98 to 300 KL a month	Not applicable as all of them use municipal water	Not available (they received their bills based on consumption)
Municipality or Water Services Authority 3	There are very few laundries but their impact is limited, not dealing with them	Not applicable	Do not deal with laundries	Do not deal with laundries	Do not deal with laundries	Do not deal with laundries	Do not deal with laundries	Do not deal with laundries
Municipality or Water Services Authority 4	There are many; cannot provide a full list	List supplied of various laundries	Alkalinity, COD, pH and EC	Not available general trends are as follows: COD: 345-600 pH often > 10 EC: 45-120 Alkalinity: 90-350	No information filed as most of them use municipal water and electricity	They have prepaid meter and are billed according to their use	Those who use groundwater deal directly with DWS (in terms of license and monitoring)	On their municipal bills

Institution	Questions and response							
	Q1	Q2	Q3	Q4	Q5	Q5.1	Q5.2	Q5.3
Municipality or Water Services Authority 5	There are many; no up to date database		pH, COD, alkalinity	To be provided later	Yes	To be provided	Not available (request from DWA)	To be provided
Municipality or Water Services Authority 6	No database; only random check for some laundries in the area	Cannot provide names for confidentiality reasons	Alkalinity, TDS, EC, pH and COD	Values vary with time. Range value between 2014 to date are: pH: 9.1 to 12,3 TDS: 120-315 EC: 85-125 COD: 125-380	Yes, depend on available information	Variable according to the usage and size of the laundry (in terms of washing load) Lowest: 120 KL Highest: 1,800 KL	Where ground water is used, they deal with DWA	Not concerned with energy use
Municipality or Water Services Authority 7	There few laundries but the list is not available	Three medium-sized to large laundries	COD, conductivity, pH	COD:<20-1535 Conductivity: 66 -319 pH: 8.9-9,9 See attachment	Yes if information requested is available	10/15: 2357 KL 11/15: 3027 KL 12/15: 3952 KL 01/16: 2776 KL 02/16: 2740 KL	Not considered	09/15: 22109Kwh 10/15: 23982Kwh 11/15: 25468Kwh 12/15: 28529Kwh 01/16: 22687Kwh (see attachment)
Municipality or Water Services Authority 8	No available /reliable database as many of these laundries opens and closes…		Random test: pH, alkalinity and COD			To be provided	Not applicable as many use municipal water	Billed according to the use – no database available
Municipality or Water Services Authority 9	No database	Random check (cannot provide names)	pH, alkalinity, conductivity	Range values pH: 8.7-11.2 Alkalinity: 56-345 Conductivity: 46-126	Yes	Average: Sep 15: 420 KL Oct 15: 260 KL Nov 15: 310 KL Dec 15: 216 KL Jan 16: 234 KL	Not applicable as the focus is on only water supplied by Erwat	Not checked (not dealing with energy usage)

CHAPTER 8: WASTEWATER MANAGEMENT: BEST PRACTICE

8.1 TREATMENT OPTIONS

It is essential for commercial laundries to be economically efficient, environmentally friendly and sustainable. The current NATSURV 8 will be more elaborate regarding treatment options for commercial laundries to consider. An extensive review was conducted, and the information that is available regarding the optimisation of water, energy and wastewater practices is mentioned.

a. Sinner's Circle

Before discussing the optimisation of water, energy and wastewater practices, it is necessary to mention Sinner's Circle. It consists of four parameters that influence the laundering process, thereby indirectly influencing the impact that water, energy and wastewater processes have on a laundry industry. Sinner's Circle refers to the influence of time, temperature, chemicals and mechanical action on the washing performance. Time refers to how long laundering processes take, temperature to the temperature at which these processes take place, chemicals to the type and amount of chemicals used for each process and mechanical action to the influence of the machine's design and physical action on the textiles. An example of measures taken to optimise the effect that Sinner's Circle has on washing performance is indicated in Figure 8.1. Each parameter has a direct influence the other (e.g. if the temperature for the washing and rinsing stages are increased, the amount of chemicals used at those stages can be lowered) (*Training Modules on the Sustainability of Industrial Laundering Processes, n.d.*).

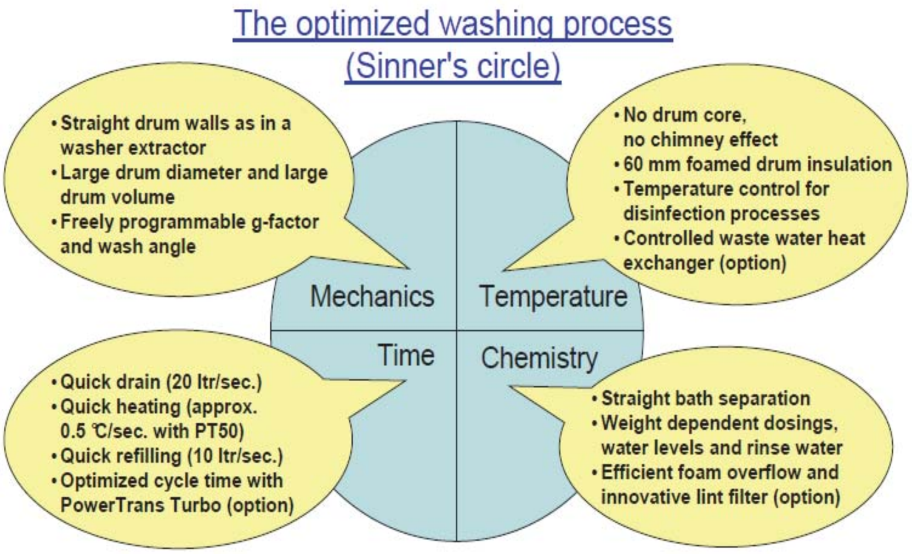


Figure 8.1: Example of how Sinner's Circle can be used to identify potential measures to optimise washing performance (adapted from *Training Modules on the Sustainability of Industrial Laundering Processes*)

8.2 TREATMENT CONFIGURATIONS

It is recommended that more economic and simple wastewater treatment processes should be reviewed and implemented first before proceeding with more sophisticated options. Emphasis is placed on the control of pH and the removal of solids.

The control of pH is essential since municipalities generally limit the wastewater they receive to a pH range between 5 and 9. Failing to adhere to this pH range would incur an avoidable extra charge to the laundry. The highly alkaline wastewater generated by commercial laundries can be treated with an acidifying chemical. This dosage option is only advisable if its cost does not exceed the extra municipal tariffs mentioned.

The only solids in laundry wastewater are colloidals or tiny particles suspended in water. Colloidals will not settle out unaided so coagulation and flocculation chemicals can be added to assist in the sedimentation process. The chemicals used are water-soluble electrolytes and polymers. The coagulation/flocculation process should be carried out in a specially designed basin or tank to promote floc growth and settlement. These tanks may be circular or rectangular vertical flow, radial flow or horizontal flow types. Thus, for a relatively small capital outlay for a settling tank and some chemical dosing equipment, a considerable improvement in the quality of the wastewater can be expected, with concurrent savings in municipal wastewater treatment charges.

For further treatment of laundry wastewaters, perhaps for reuse of rinse water as well as wash water, more sophisticated treatments may be necessary. These processes are all capital intensive and would only be worth considering as a second stage after simple wastewater treatment and management measures had been implemented. The following options are mentioned:

- Cross-flow microfiltration: A pressure-driven filtration process for the removal of suspended and colloidal particles.
- Dissolved air flotation (DAF): Operates by dissolving air under pressure in the wastewater and then allowing this wastewater to suddenly return to atmospheric pressure. The dissolved air forms tiny bubbles which adhere to any solid material in the wastewater and floats them to the surface where they can be removed easily.
- Ultra-filtration (UF): Membranes are used to mechanically separate SS from a liquid solution. The UF process can be used to separate out large organic molecules from solutions. Treated wastewater (after dissolved air flotation and/or UF), as far as bacteriological quality is concerned, has been found to have no *E. coli* bacteria present. If necessary, the treated wastewater could be chlorinated prior to reuse.

REFERENCES

Ahmad, J. & El-Dessouky. 2008. Design of a modified low cost treatment system for the recycling and reuse of laundry waste water. *Resources, Conservation and Recycling*, 52(1):973-978.

Ahn, K.H. & Song, K.G. 1990. Treatment of domestic wastewater using microfiltration for reuse of wastewater. *Desalination*, 126(3):7-14.

Australian Bureau of Statistics. 2008. *Environmental issues: Energy use and conservation*. Australian Bureau of Statistics, Canberra.

Bidvest Laundry Group. n.d. [Online]. Available online at: http://www.bidvestlaundrygroup.co.za/news/hostex-2012.aspx [2014, 22 April].

Brown, A. 2009. *Laundries water efficiency program: Options*. Yarra Valley Water Report, Melbourne.

CBW batch washers. n.d. [Online]. Available online at: http://www.bidvestlaundrygroup.co.za/montana-laundries/milnor-cbw-system/milnor-cbw-system-cbw-batch-washers/milnor-cbw-system-cbw-batch-washers.aspx [2014, 18 April].

Chemical Engineering Branch (CEB), 2006, *Site Visit Report – Nixon Uniform Service and Medical Wear – Industrial and Institutional Laundries Generic Scenario*, USEPA Office of Pollution Prevention and Toxins; Chemical Engineering Branch; Washington, DC; 14 February 2006.

Chen, Z., Ngo, H.H. & Guo, W.S. 2013. A critical review on the end uses of recycled water. *Critical Reviews in Environmental Science and Technology*, 43(1):1446-1516.

Ciabatti, I., Cesaro, F., Faralli, L., Fatarella, E. & Tognotii, F. 2009. Demonstration of a treatment system for purification and reuse of laundry wastewater*. Desalination*, 245(1):451-459.

Cloete, T.E., Gerber, A. & Maritz, L.V. 2010. *A first order inventory of water use and effluent production by South African industrial, mining and energy generation sectors*, Research Report No. 1547/1/10, Water Research Commission, Pretoria, South Africa.

Dry cleaning and laundry facilities. 2005. [Online]. Available online at: http://classic.edsuite.com/proposals/proposals_169/85_3_intel_dry_cleaner_and_laundry.pdf [2014, 20 April].

East Bay Municipal Utility District. 2008. *Watersmart guidebook: A water use efficiency plan review guide*. East Bay Municipal Utility District, California.

Environmental Dossier on Professional Laundry. n.d. [Online]. Available online at: www.aise-net.org/downloads/AISE_pro_laundry_dossier.pdf [2014, 19 August].

Environmental Protection Agency. 1997. *Water quality benefits analyses for proposed pretreatment standards for existing and new sources for the industrial laundries point source category*. Environmental Protection Agency, Washington, DC.

Environmental Protection Agency. 2000. *Technical development document for the final action regarding pre-treatment standards for the industrial laundries point source category*. Environmental Protection Agency, Washington, DC.

European Textile Services Association (ETSA), 2010, *Environmental assessment of laundry detergents*. Accessed on 27/08/2015. Available online at: http://www.eco-forum.dk/detergents/index_files/Page435.htm

European Textile Services Association. 2014. *Clean technology enables professional laundry industry to reduce resource consumption and environmental impact*. European Textile Services Association, client communication.

Fijan, S., Fijan, R. & Sostar-Turk, S. 2008. Implementing sustainable laundering procedures for textiles in a commercial laundry and thus decreasing wastewater burden. *Journal of Cleaner Production*, 16(1):1258-1263.

Gosolits, J. 1999. *Waschmittel und wasserrecycling in gewerblicher und krankenhauwaeschereien*. BekLeidungs-physiologisches Institut Project report, Hohenstein.

Gruttner, H. 2013. *ETSA Survey on resource consumption in workwear laundries and flat linen laundries in 2011 – WECO 3*. European Textile Services Association, Final report.

Hloch, H., Tokos, M., Spettmann, D., den Otter, W.A.J.L., Groosman, M., Vanderhoeven, M., Pušić, T., Šostar, S., Fijan, S. & Seite, M. 2012. *Sustainable measures for industrial laundry expansion strategies: SMART-laundry-2015*. SMILES Report, European seventh framework programme.

Hoinkis, J. & Panten, V. 2008. Wastewater recycling in laundries – from pilot to large-scale plant. *Chemical Engineering and Processing*, 47(1):1159-1164.

Industrial energy efficiency accelerator. n.d. Available online at: https://www.carbontrust.com/media/206508/ctg064-laundries-industrial-energy-efficiency.pdf [2014, 18 April].

Janpoor, F., Torabian, A. & Khatibikamal, V., 2011, Treatment of laundry waste-water by electrocoagulation. *Society of Chemical Industry*, 86(1):1113-1120.

Kirk-Othmer, 2004, 'Detergency' and 'Bleaching Agents', Kirk-Othmer Encyclopaedia of Chemical Technology, John Wiley & Sons, Inc.

Kist, L.T., Albrecht, C. & Machado, E.L. 2008. Hospital laundry wastewater disinfection with catalytic photoozonation. *CLEAN-Soil, Air, Water*, 36(9):775-780.

Koch Membrane Systems. 2004. Available online at: www.kochmembrane.com [2014, 20 August].

Laundry Process Layout. n.d. Available online at: http://nagarjun-itc.com [2014, 20 August].

Lu, W. & Leung, A.Y.T. 2003. A preliminary study on potential of developing shower/laundry wastewater reclamation and reuse system. *Chemosphere* 52(1):1451-1459.

Máša, V., Bobák, P., Stehlík, P. & Kuba, P. 2013. Energy intensive process in professional laundry service: Up-to-date approach. *Chemical Engineering*, 35(1):259-264.

Murphy, K.O.H. 2007. *A scoping study to evaluate the fitness-for-use of greywater in urban and peri-urban agriculture*. Research Report No. 1479/1/06, Water Research Commission, Pretoria, South Africa.

Organisation for Economic Co-operation and Development (OECD), 2011, *Emission scenario document on the chemicals used in water based washing operations at industrial and institutional laundries*, OECD Environmental Health and Safety Publications, Document No. 29.

Pakula, C. & Stamminger, R. 2010. Electricity and water consumption for laundry washing by washing machine worldwide. *Energy Efficiency* 3(1):365-382.

Princes Fabricare Commercial Laundry Case Study. n.d. [Online]. Available: http://www.hydrasyst.com/wp-content/uploads/2013/03/Commercial-Laundry-Case-Study.pdf [2014, 23 April].

Raghava, R.J., Chandrababu, N.K., Muralidharan, C., Nair, B.U., Rao, P.G. & Ramasami, T. 2003. Recouping the wastewater: a way forward for cleaner leather processing. *Journal of Cleaner Production*, 11(1):591-599.

Seneviratne, M. 2007. *A Practical Approach to Water Conservation for Commercial and Industrial*. Oxford: Elsevier Ltd.

Seo, G.T., Lee, T.S., Moon, B.H. & Lim, J.H. 2001. Ultrafiltration combined with ozone for domestic laundry wastewater reclamation and reuse. *Water Science and Technology: Water Supply*, 1(5):387-392.

Shove, E. 2003. Converging conventions of comfort, cleanliness and convenience. *Journal of Consumer Policy,* 26(4):395-418.

Sostar-Turk, S., Petrinic, I. & Simonic, M. 2005. Laundry wastewater treatment using coagulation and membrane filtration. *Resources, Conservation and Recycling*, 44(1):185-196.

Steffen, Robertson and Kirsten Inc. Consulting Engineers. 1989. *NATSURV 8: Water and wastewater management in the laundry industry*. Water Research Commission report 145, TT42/89, Pretoria.

Training Modules on the Sustainability of Industrial Laundering Processes. n.d. [Online]. Available: http://www.laundry-sustainability.eu [2014, 28 April].

Uniform and Textile Service Association (UTSA), 2005, *Comments on Chemicals Used in Water-based Washing Operations at Industrial and Institutional Laundries – Generic Scenario for Estimating Occupational Exposures and Environmental Releases* – December 8, 2004 Draft, 16 September,

United States Environmental Protection Agency (USEPA), 1999, *Catalogue and Assessment of Components and Ingredients in Laundry Detergent Formulations*, U.S. EPA Internal Document, June 1999.

Water usage breakdown. n.d. [Online]. Available: http://www.savewater.com.au/how-to-save-water/in-business/laundries/water-usage-breakdown [2014, 17 April].

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