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Water Management at a textile industry:

a case study in Lesotho

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Water Management at a textile industry: a case study in Lesotho

By

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Declaration Statement

I, Tholoana Marcelina Masupha, hereby declare that the work as contained in this document was compiled and set out by myself and it has not been submitted to any other university.

SIGNED ON THE 19 JUNE 2007.

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Tholoana Marcelina Masupha

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Abstract

Textile industries use large amounts of water in their production processes, with subsequent generation of large quantities of wastewater. With ineffective and/or inefficient water management protocols in place, these industries can have a large negative impact on the environment. In order to assist in the development/setting of suitable actions to negate environmental impacts from textile industries, it is essential that some form of water management, and more particularly a water balance, be in place. This dissertation investigated the current practices at a textile industry in Lesotho, CGM Industrial, as a case study with the ultimate objective to assess and present suitable water management actions to negate the company's negative impact on the environment.

An active water balance was compiled for one of the company's factories, CGM 1, and illustrated that large volumes of water (up to 0,9 Ml/day) are discharged to the natural water course, often untreated. The water balance specifically addresses water usage for the four wet processing combinations present at CGM 1, and representative of the textile industry as a whole, namely stone washing/washing, stone washing/bleaching, stone washing/dyeing and stone washing/bleaching/dyeing operations.

Based on the water balance results and general assessment of operating practices in place at CGM 1, suitable water management actions were recommended for reducing wastewater volumes, substitution and reduction of process chemicals, and investigating process modifications.

KEYWORDS: water management, textile industries, water balance

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ABBREVIATIONS

CGMI	-	CGM Industrial Pty (Ltd)
DAF	-	dissolved air flotation
SADC	-	Southern African Development Community
SW/B	-	stone washing/bleaching process combination
SW/B/D	-	stone washing/bleaching/dyeing process combination
SW/D	-	stone washing/dyeing process combination
SW/W	-	stone washing/washing process combination
TSS	-	total suspended solids
WASA	-	Water and Sewerage Authority

CHAPTER 1

Introduction

There are three major industries in Lesotho, namely the agricultural primary sector, a secondary manufacturing sector (textiles and electronic products) and a public services sector. The textile industrial sector is established at four sites, two of which are in Maseru, the capital city of Lesotho, and the other two are in the Leribe district. The textile industry plays a major role in the country's economic growth and employment creation. It contributes about 40-45 % of the country's Gross Domestic Product and employs over 40 000 Basotho, which makes it the second largest employer after the government (MNR, 2002).

Unfortunately the textile industry is also an industrial sector that uses vast amounts of water, exerting increased pressure on available natural resources. Water as a resource experiences this pressure in Maseru, where two of the country's textile industries are situated. Water is Lesotho's primary natural resource and even though it is considered abundant, seasonal and annual variations makes it a scarce resource (MNR, 2002). For example, the capital Maseru is already in a critical water shortage situation. The total water supplied to the city amounts to 28 Ml/day, of which more than one third (12 Ml/day) is used by the textile industries, with 1,8 Ml/day lost due to evaporation and spillages, and the rest discharged as effluent (Gibbs and Gibbs, 2002).

The effluent from the textile industries is loaded with various chemicals and dyes from the wet processes involved within the industry. Until mid 2004 there has been no form of treatment for any effluent from the Maseru based industries. All effluents have been discharged into the Mosenyathe stream, finally ending up in the Mohokare River. For this case study, the water management at CGM Industrial in Maseru will be investigated. The effluent produced from this textile industry is now treated in a wastewater treatment plant, with a portion of the treated water returned to the washing and dyeing plant for reuse and the remainder discharged. On occasions, untreated water is discharged into the

Mosenyathe stream to avoid overflow of the treatment plant, resulting in water quality problems downstream from the CGM Industrial site.

The objectives of this dissertation are to:

- evaluate current water management practices at CGM Industrial,
- compile an active water balance for the company, and
- present suitable water management actions to negate the company's negative impacts on Lesotho's scarce water resource.

In Chapter 2 a literature survey outlining the normal practices and principles of water management in textile industries in general will be addressed. The background of CGM Industrial will be discussed in Chapter 3, including current processes, chemical and water used at the company. An active water balance is compiled in Chapter 4 and conclusions and recommendations based on the investigation given in Chapter 5.

Research Methodology

Given the objectives of this dissertation, the critical part for their achievement will be obtaining data for compilation of the water balance for the company. The results from the water balance will assist in presenting suitable water management actions for the company.

Prior to collecting water balance data, personal interviews will be held with the management of CGM 1 (as representative of CGMI), the personnel in charge of the wet processing section as well as the workers at the wastewater treatment plant. This is to obtain and evaluate the current water management practices at the company.

Twenty four days (1 working month) will be spent at the industry for collection of data and inspection of the overall production processes entailed within the company. It is believed that this will provide sufficient data to represent what happens within the company each month. The type of data collected will be more of a quantitative than a qualitative nature. This is based on the objectives of the dissertation, which are compiling a water balance (quantitative data) and using the results of this data in assisting the company to develop a comprehensive water management plan. During the time spend at the company, overall water and chemical usage in the washroom will also be observed and this will be outlined in the conclusions and recommendations in Chapter 5.

During the twenty four days of data collection, the number of loads processed for each of the four wet processing combinations will be noted. Each process combination consists of various wet processing operations and the amount of water used for each process differs depending on the operations entailed in each. Each process will be assessed and the amount of water consumed will be used in compilation of the water balance for each.

In order to compile a comprehensive water balance, additional data with regard to water usage within the company, other than the process water, will also be obtained. This data includes water used for steam, cleaning water, checking water, water used for ablution facilities, drinking water, as well as water used for personal hygiene. All these water streams constitute the input water into the company, which should essentially be equal to the water leaving the company, as there are no big water storage facilities at the company. It is anticipated that exit water streams will most likely be confined to process wastewater, evaporation water, water absorbed by stones, as well as drinking and ablution facilities wastewater.

The amount of water used at the company will be presented either from direct data collection of the amount used for each of the process combinations for the number of loads processed during the twenty four days spent at the company, or through assumptions made due to lack of readily available data. Water discharged from the company will also be assessed based on interviews with the personnel responsible for the wastewater treatment plant, as well as from assumptions made during the data collection period (should sufficient monitoring and sampling/analyses of discharge water not be available). Using data obtained as set out above, active water balances for each process combination will be compiled and conclusions and recommendations will be made based on the outcome of the overall water balance for the company.

CHAPTER 2

Literature Survey

2.1 SUSTAINABLE WATER RESOURCE MANAGEMENT

Water has not been considered as a non-renewable resource until the end of the 1960s or beginning of the 1970s (Alvarez *et al.*, 2003). Moreover, it was believed that the resources in the natural environment were limitless. That is the reason why the economic cost of water was not important relative to the total cost of industrial activities. Nowadays, it is clear that water is a natural resource essential for every human activity. Thus, it is necessary to minimise its consumption and to return it back to the environment with the minimum contamination load because of the limited capacity of self-purification. This is the basis of sustainable water resource management (Alvarez *et al.,* 2003).

The goal of sustainable development is the enhancement of the quality of life for present and future generations, while maintaining the integrity of ecological systems (DWAF, 1996). This entails the reduction of the exploitation of natural resources and the reduction in pollution, which degrades resources and is a measure of their inefficient use (Edwards, 1996). Water is one such natural resource that is of vital importance for life and economic activity. The over exploitation of water can result in pollution, degraded habitats and depleted river and groundwater levels (Edwards, 1996). The sustainable management of the water environment requires the regulation of both the quantity of water available and its quality (Edwards, 1996), resulting in water being one of the primary considerations during sustainable planning.

In the context of water resources, the concept of sustainability resource use is the one where, with effective management, the rate of resource withdrawal, use, consumption or depletion is always balanced, or preferably exceeded, by the rate of resource replenishment (PRG, 1990). However, sustainability should not be confused with zero growth. The concept of sustainable development stresses the interdependence of economic growth and environmental quality (Barclay *et al*., 2002a). It should be understood that sustainable development entails achieving a balance between protecting the natural resources and allowing economic growth to take place through a rational and carefully managed use of available resources (PRG, 1990). Limits should not be set on economic activity in the interests of preserving the environment, but also the environment should not be used at the expense of economic growth (PRG, 1990).

It is the duty of those responsible for the management of the environment to ensure that any development takes place without disruption to the balance of the environment and in a manner that is sustainable in terms of its economic viability and the welfare of its community, as well as its effect on the environment (Carroll, 1997). The benefits accruing from good environmental management of companies are most often linked to economic benefit and the concept of moving towards sustainable development (Young, 1996). However, the link between environmental liabilities, assets or performance and the financial valuation remains obscure at best (Edwards, 1996). According to Young (1996), operational improvements such as implementing a waste minimisation programme, can give a clear short-term reduction in costs and impact immediately on profits.

Streams are no longer just a means of waste conveyance to the oceans, but valuable resources, which can be used and reused for many purposes (Nemerow, 1971). The pollution-carrying capacity of streams must be protected and preserved by all consumers and utilised in ways that are beneficial to all society (Nemerow, 1971). The ability of all nations and society to develop and prosper is tied directly to their ability to properly develop, utilise, protect and sustain their water resources (DWAF, 1996). The ultimate achievement of these objectives is dependant on the implementation of an appropriate system that ensures the long-term sustainability of both the water resources and the uses that are made of them (DWAF, 1996). It is therefore necessary that all industrial sectors in Lesotho adapt to activities that will help achieve sustainable water resource management.

2.2 LEGISLATION IN LESOTHO

All over the industrial world legislation with regard to the discharge of industrial effluent is being improved, resulting in many industries, which have not previously considered wastewater as any problem at all, starting to evaluate wastewater treatment methods, the feasibility of changing the quality and/or the quantity of wastewater and the profitability of complete or partial recirculation and recovery of process water (Jorgensen, 1979).

In Lesotho the challenge lies with enforcing legislative measures on polluters in order to achieve sustainable water resource management. Although there is a legislative framework in place, which deals with the regulation of supply of water and wastewater services to industries, the level of enforcement is limited. The framework consists of The Water Resources Act (No 22 of 1978), Lesotho Water and Sewerage Authority Regulation (No 173 of 1992), Lesotho Water and Sewerage Authority Order (No 29 of 1991) and The Environment Act (No 15 of 2001).

The Water Resources Act entails the use, control, protection and conservation of water resources. Pollution is outlined to be an offence under the Act and a water officer is given the power to request a polluter to take measures for preventing pollution. The Environment Act addresses the management of the environment and all natural resources of Lesotho for sustainability of Basotho livelihood, through sound environmental management. This Act defines the general principles of the broad activities of environmental management in Lesotho. It also guarantees each individual the right to a clean and healthy environment. It imposes a duty to protect, maintain and enhance the environment on all citizens of Lesotho and defines a right to citizens to take legal action against perpetrators damaging the environment (NES, 2002).

Due to limited enforcement of the law on polluters, a number of industries have not found it necessary to invest in pollution prevention and waste minimisation; as these industries face difficult choices of distributing a limited pool of financial and technical resources over a myriad of pollution prevention and waste minimisation facilities (Roth, 1964). However, coordinated environmental planning and management can help to control, reduce and/or minimise the occurrence of undesirable impacts on water resources by reducing the consumption of resources, waste production and disposal requirements; as well as treatment and energy costs (Carroll, 1997).

The implementation of effluent management systems at textile factories will involve the development of various options to minimise water consumption and meet pollution abatement requirements (PRG, 1990). These options will require, *inter alia*, well-rehearsed procedures and easily accessible and well documented, user-friendly information systems (to support decision making processes), to ensure that problems associated with water quality are managed in a competent and professional manner, particularly when public health is at risk (Buckley, 1997).

2.3 BACKGROUND TO THE TEXTILE INDUSTRY

Industrial development is one approach to increasing the quality of life in most less developed regions of the world. The potential benefits of development can be greater prosperity, followed by better health and lower birth rates (Moore and Ausley, 2003). However, the darker side of industrial development should not be ignored, which is pollution, caused by ignoring the principles of cleaner production. The textile industry in developing regions of the world is currently faced with a number of challenges, particularly with respect to environmental legislation and international competition. Environmental-related issues include increasing cost of water, increasing cost of effluent treatment and/or disposal, more stringent regulations being implemented, especially in terms of colour, toxicity and salinity; and the introduction of ISO 14001, ecolabels and new legislation (Barclay *et al*., 2002b).

In order to meet these challenges, an industry must develop proactive water, air and waste management procedures. This can be achieved by implementing environmental and quality management systems that incorporate concepts of water and waste minimisation. Due to increasing competition between companies and strict measures in enforcing environmental legislation, a number of industries have started incorporating clean technologies into their productive processes, such as technologies with less consumption of natural resources and with less generation of waste (Alvarez *et al*., 2003). These industries have come to realise that operations and activities within their companies somehow interact with the environment and they should bare the responsibility of protecting the environment.

The textile industry is a highly hand labour intensive industry. This is the reason of its popularity in less developed countries, where there is abundance of cheap labour. High labour costs in the United States of America have led to the transfer of the textile industry into the less industrially developed regions of the world, where less expensive and less stringent enforcement of environmental regulations results in lower production costs, at least in the short term (Moore and Ausley, 2003). Current trends indicate that the United States' textile industry is moving into the Far East, South America and Africa (Moore and Ausley, 2003). The movement of textile industries into largely under developed regions of the world with inadequate water and waste treatment presents the opportunity for large-scale negative environmental impacts, because these regions commonly lack extensive industrial wastewater treatment infrastructure.

The textile industry represents a range of industries with operations and processes as diverse as its products (Wang and Wang, 1992). It is almost impossible to describe a "typical" textile effluent because of such diversity. The operations in the industry consist of a number of processes, some of which are highly water intensive. In textile processes, water is used to remove natural impurities and to wash out chemicals, with substantial amounts of water required to keep concentrations low and allow diffusion processes to proceed (Little, 1970). Any reduction in water usage gives liquors that are proportionally stronger, and a limit is reached where further changes may be detrimental to the valuable textile materials (Little, 1970). This can work against the idea of altering processes to conserve water and limit pollution.

Textile effluents are a mixture of acidic and alkaline solutions, heavily laden with chemicals in varying concentrations due to the nature of batch processing. The wet processing requirements also differ with regard to temperature and water levels, which result in fluctuations in temperatures; cold rinsing waters merging with very hot dye liquors, as well as flow rates of effluents (Little, 1970). The discharges containing such mixtures of components, with rapid fluctuations in chemical concentrations, pH of batches, temperature and flow; present many problems in measurement of flow and composition. The planning for stable treatment conditions of such effluents must therefore include facilities for achieving better uniformity by mixing and balancing the effluents (Little, 1970). It is thus very important to know the various operations involved in textile industries before problems associated with the wastewater produced from this industry are dealt with.

2.4 THE TEXTILE PROCESS

Although denim fabric manufacturing is not in the scope of this dissertation, it is essential to discuss some basics in order to be familiar with the terms used in the sections to follow. In denim fabric manufacturing, the fibres undergo a number of processes before being woven together on a loom to produce the fabric. A loom is an apparatus used for weaving yarns (threads spun from the fibres) into fabric. For the fabric to be produced, two types of yarns are used, namely warp yarns and weft yarns. The warp yarns stretch lengthwise or horizontally in a loom being crossed by the weft yarns, which run vertically on the loom while crossing the warp.

In denim manufacturing, the warp yarns are dyed and strengthened before being woven into fabric, while the weft yarns retain their original colour and strength. The warp yarns are dyed in indigo, which is a blue dye with unique characteristics. Indigo is characterised by good colourfastness to water and light, continually fading and its inability to penetrate fibres completely. This allows the blue colour in jeans made from indigo to always look irregular and individual. The process of strengthening the warp yarns is referred to as either sizing or slashing, and is accomplished by treating the yarns with starch or other substances like polyvinyl acetate. The substances used in the sizing/slashing process are referred to as “size”. The dyed and “sized” warp yarns are then crisscrossed by the weft yarns and woven into a denim fabric, which is then used in the textile process for the manufacturing of denim jeans.

The textile process for the manufacturing of denim jeans (see Figure 2.1) can be divided into garment manufacturing, when the actual garments are made; wet processing, which is the general term used to refer to the various washing, dyeing, bleaching and other water intensive processes within textile industries; and final dispatch, when the finished products undergo steam pressing and final packaging.

Garment manufacturing can be divided into the making of the garments, garment evaluation, preparation and metal protection. The making of the garments entails three general steps; spreading, cutting and sewing. In the spreading step, pre-dyed piles of denim material are laid on the cutting table. Pattern pieces are then placed on the layers of material and the cutting process proceeds. The cut pieces are then sewn together to make a complete garment.

In garment evaluation, the garments are evaluated for the depth of shade, construction, type of stitches, type of thread, metal in buttons and zippers, type of material making the pocket bags and the type of “size” used for strengthening the warp yarns.

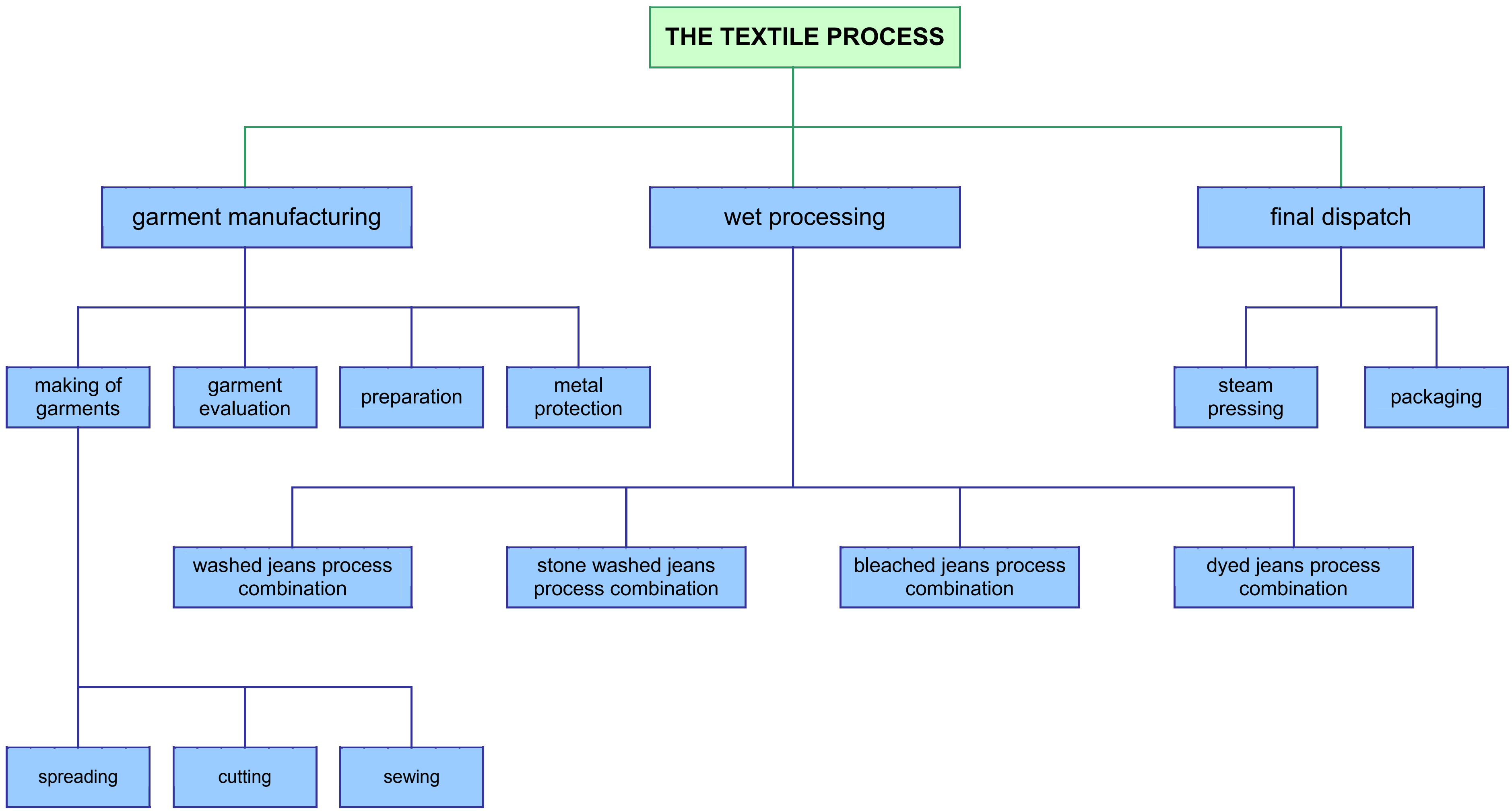


Figure 2.1 The general textile process in the garment manufacturing sector.

Preparation is the selection of the wet processing operations to be carried out on particular garments, which may be desizing, abrasion/stone washing, bleaching, neutralisation, dyeing, softening or various combinations of the above operations. In metal protection a chemical coating is used to prevent or repair oxidation and corrosion by recoating buttons, zippers, rivets, studs or any metallic accessories that may be damaged during wet processing.

After the four steps involved in the manufacturing of garments, the garments then proceed to wet processing. Textile industries deal with different types of fabrics and for each type, the operational processes and chemicals used during wet processing differ. Wet processing for the manufacturing of denim jeans involves various process combinations, for example, washing, stone washing, dyeing and bleaching. Each of these process combinations includes any number of the following wet operations: desizing, rinsing, washing, abrasion/stone washing, bleaching, neutralisation, dyeing, softening and drying.

2.4.1 Desizing

The first wet operation for jeans wet processing is always desizing. This is the removal of the non-fibrous substances (size), applied to the fabric during the sizing/slashing operation, by hydrolysing the substance into a soluble form (Jones, 1973). The non-fibrous substance is normally referred to as starch. The purpose of this step is to remove the starch/size and a portion of the indigo dye from the jeans. This significantly softens the denim and during later steps will prevent streaks from forming because the material was too hard (TTCI, 2005).

There are two common methods of desizing; acid desizing and enzyme desizing (Wang and Wang, 1992). In acid desizing, dilute sulphuric acid is used to depolymerize the starch/size and render it soluble. In enzyme desizing, vegetable or animal enzymes are used in rendering the starch soluble (Jones, 1973).

Improper desizing can cause streaks on garments. To avoid the formation of lines and streaks, it is necessary to ensure that the jeans are very well wet out during the desizing stage. This will prevent the garments setting in one position and forming creases that will turn into lines at the abrasion/stone-washing stage. Specific anti-crease agents have to be used as the wetting agents. During the desizing stage, a lot of indigo is removed from the warp fibre and it is necessary to add from the beginning an “antibackstaining” agent to avoid too high redeposition of blue indigo on the “white” weft fibre.

2.4.2 Rinsing

The rinsing wet operation follows after every operation to remove or rinse off the chemicals used. In rinsing, only water is used and no detergent or chemical is added.

2.4.3 Washing

The washing operation is also known as a rinse wash. In the rinse wash, the garments are washed with water and a detergent at about 50^0C, rinsed and then softened. Due to the high temperatures, there is a high risk of colour bleeding and the garments somehow still lose a bit of colour. This operation is normally done on garments that are not to be stonewashed. However, it may also be done on garments after stonewashing to remove residual pumice stone fragments.

2.4.4 Abrasion/stone washing

The abrasion wet operation is normally referred to as stone washing and normally takes place after the first rinse following the desizing operation. It entails the use of stones to accelerate the abrasion or fading (colour loss) and softening of garments (usually jeans). The stones can be natural (pumice) or synthetic. The rock ratio, size and hardness of the stone are very influential in the look achieved during this operation of wet processing (Chemical Technologies, 2001).

Stone washing is carried out in the presence of enzymes. The enzymes are used to assist in the abrasion without extensive loss of tear tensile strength. The enzymes also act as activators which swell the cotton to enhance the abrasive action of the pumice stone on the denim and to suspend particles in the wash liquor preventing redeposition onto the garment (Chemical Technologies, 2001). However, too much enzymes during stonewashing can also exaggerate streaks by enhancing the abrasion on the creases too quickly (SAI, 2001), as well as lead to garment fraying. (Garment fraying is the unweaving of the edges of the garments due to the weakening of the fabric.) The stones used should also be in the right volume and size and the time interval for the process strictly adhered to, otherwise the tensile strength of the fabrics will be lost and fraying will occur.

2.4.5 Bleaching

Bleaching is the removal or reduction of the amount of colouring on fabrics, thus rendering them white. Bleaches that are commonly used for denim jeans wet processing are sodium hypochlorite and hydrogen peroxide. In hypochlorite bleaching, the fabric is rinsed, saturated with a weak solution of sulphuric or hydrochloric acid, rinsed again and then passed through the hypochlorite solution (Jones, 1973). This wet operation is carried out under room temperature at a pH of between 9 and 11.

Hydrogen peroxide is used for continuous bleaching. This entails a first washing process of the jeans in a water bath at approximately 60^{o}C – 80^{o}C, followed by saturation with caustic soda at approximately 80^{o}C – 82^{o}C. The jeans are then passed through a bath of hydrogen peroxide at approximately 90^{0}C and a final rinse (Jones, 1973). The pH for this kind of bleaching ranges between 9 and 10. The pH during the bleaching operation should not go below 9, as below this pH the cellulose degrades to form oxycellulose, thus weakening the fabric (SAI, 2001). The bleaching cycles should also be short to avoid fraying. Two bleach cycles may rather be carried out if lighter colours are desired.

2.4.6 Neutralisation

After bleaching, the denim jeans are neutralised. The residual chemicals on the jeans from the bleaching operation are neutralised by passing the fabric through a bath of sodium bisulfite ($NaHSO_3$) or sulphur dioxide (SO_2) in water (Jones, 1973). This very important wet operation after bleaching entails using a reducing agent to stop the reaction of the bleach. The agents are usually catalysts, which are not used up in the neutralising operation. Improper neutralisation, for example, leftover of chlorine in the garments, causes yellowing (yellow marks present on the garments) and also leaves the garments with a pungent smell. Neutralisation cycles should be done at high temperatures and with large amounts of water.

2.4.7 Dyeing

The dyeing wet operation is carried out in an aqueous bath containing a paste of dye, thickener, hygroscopic substances, dyeing assistants, water and other chemicals (Wang and Wang, 1992); with pH variations of between 6 and 12 and temperature variation from room temperature to boiling (Jones, 1973). The garments are dyed in small volumes on batch process machines. The six important dye classes used on cotton fabrics are vat, developed, naphtol, sulphur, direct and aniline black (Jones, 1973). The steam used in the dyeing operation to raise the water temperature should never be injected into the batch process machines once the enzymes have been dosed, as enzymes tend to deactivate in the presence of live steam (SAI, 2001).

2.4.8 Softening

During the softening wet operation, carried out in washing machines, a fabric softener is used to give the final product a good feel and smell, which are very important aspects when the garments reach the customer. Incorrect softener use and process parameters can cause damage to the final product, for example, cationic softeners at times give garments a yellow finish.

2.4.9 Drying

The drying operation is carried out in two steps; spin drying and tumble drying. In spin drying, excess water from the softening process is drained from the garments and in tumble drying, the garments are dried and steam is produced.

2.4.10 Process combinations

A number of combinations can be made from the wet operations outlined in Sections 2.4.1 – 2.4.9 to give the final garments a finish as requested by a relevant client. Four final product or wet processing combinations, generally done at textile industries, are: washed jeans, stonewashed jeans, bleached jeans and dyed jeans.

Washed jeans

The operations involved to produce washed jeans as a final product are the desizing, rinsing, washing, softening and drying wet processing operations. This process is illustrated in Figure 2.2 and is also considered as the primary wet processing for jeans.

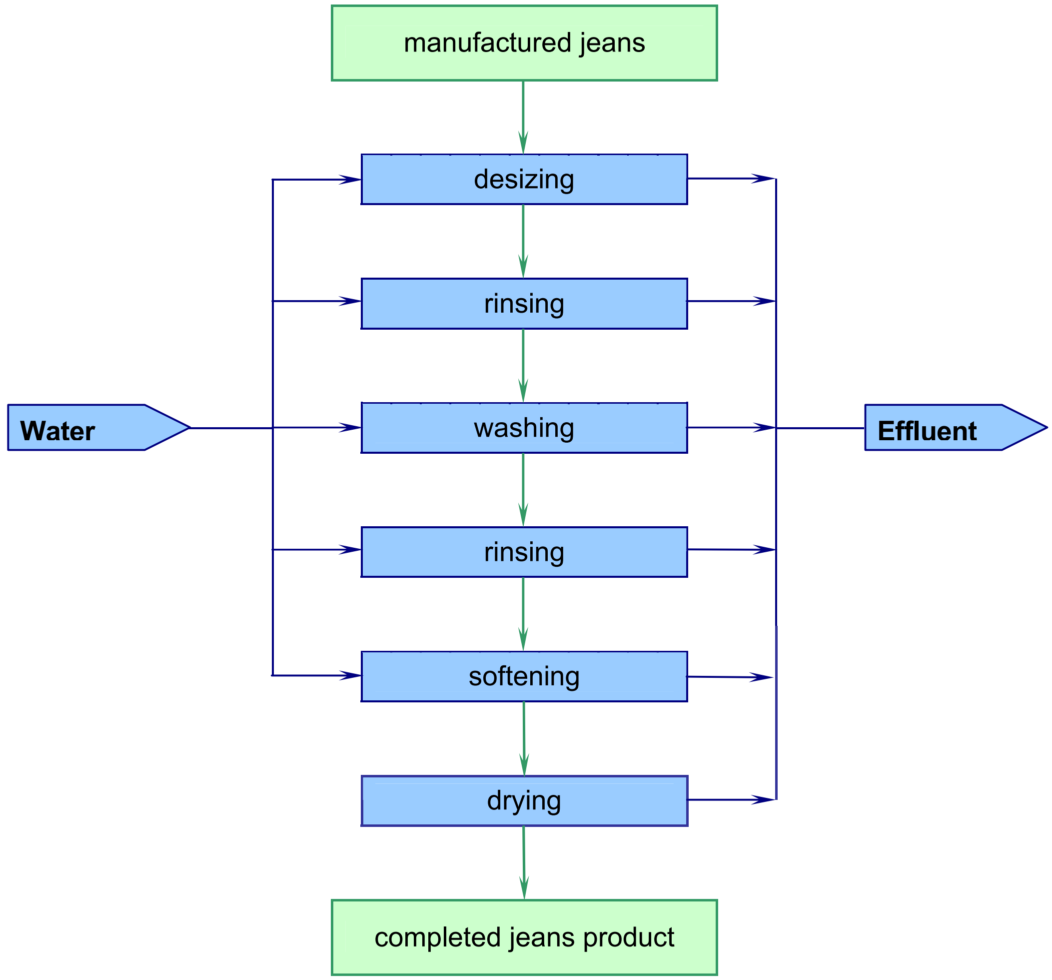


Figure 2.2 Process flow sheet for wet processing operations to produce washed denim jeans as the final product.

Stonewashed jeans

When the final product requested by a client is stonewashed jeans, desizing, rinsing, stonewashing, softening and drying represent the wet processing operations required; as illustrated in Figure 2.3.

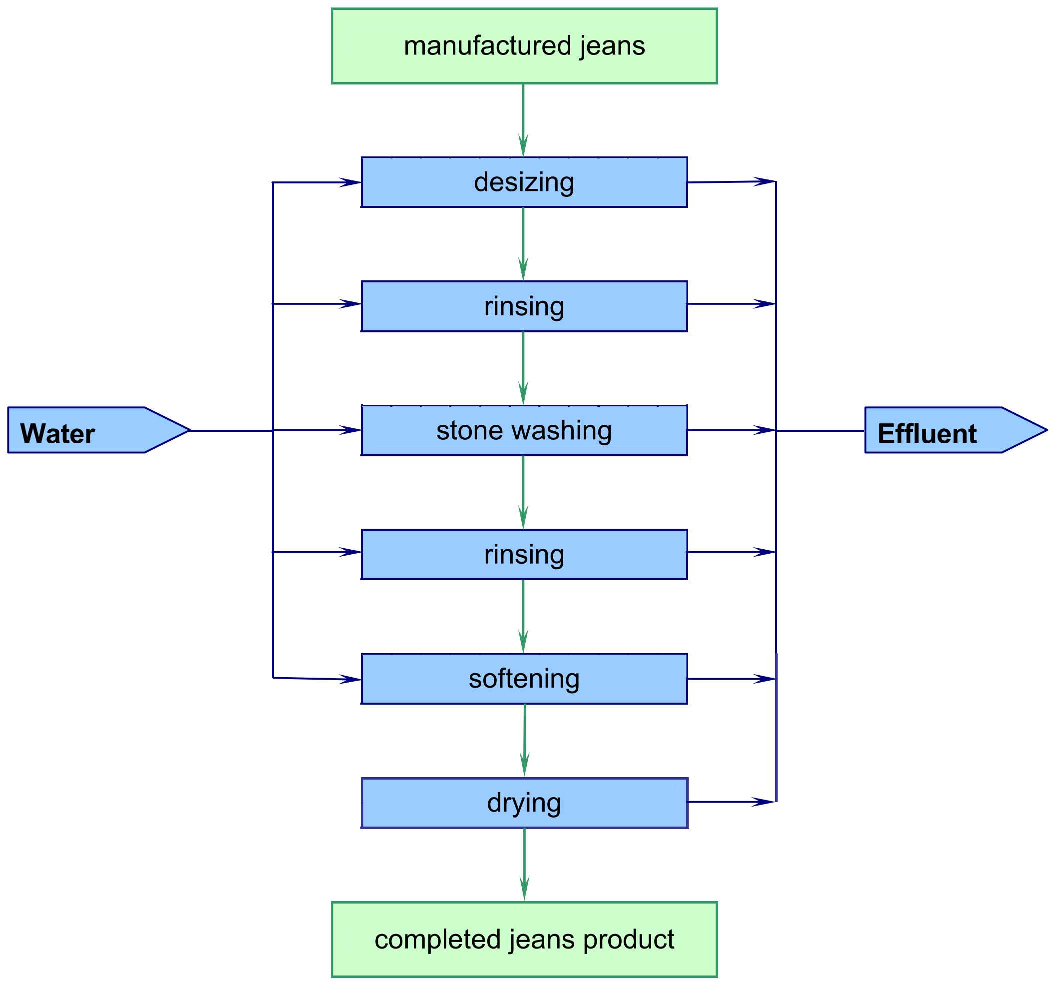


Figure 2.3 Process flow sheet for wet processing operations to produce stone washed denim jeans as the final product.

Bleached jeans

For certain types or line of jeans, bleaching may be required; resulting in the process illustrated in Figure 2.4. For bleached jeans, the wet processing operations will consist of desizing, rinsing, stonewashing, bleaching, neutralising, softening and drying.

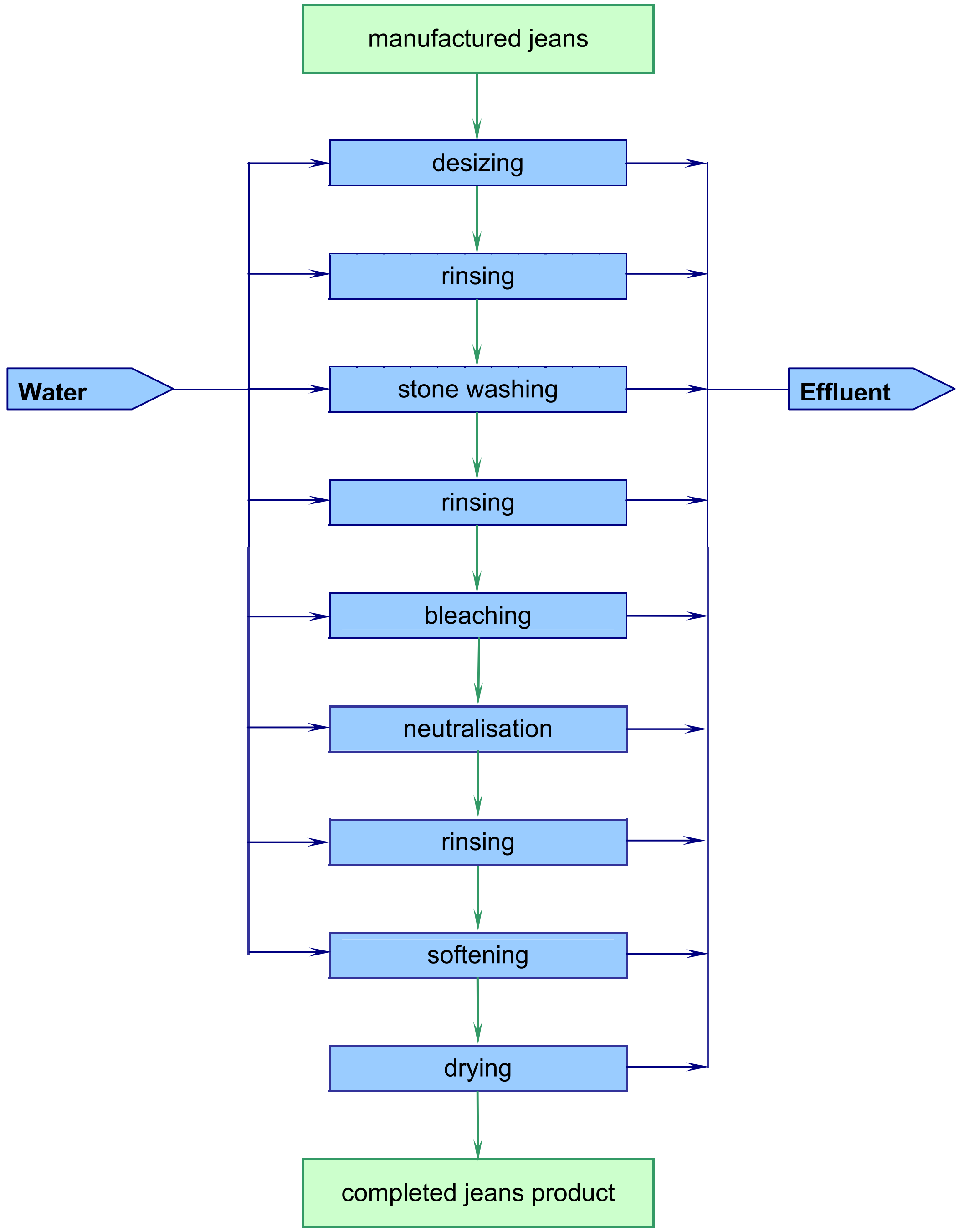


Figure 2.4 Process flow sheet for wet processing operations to produce bleached denim jeans as the final product.

Dyed jeans

In some instances dyeing of jeans is required and the basic process is given in Figure 2.5. In this case the wet processing operations will consist of desizing, rinsing, stonewashing, dyeing, softening and drying.

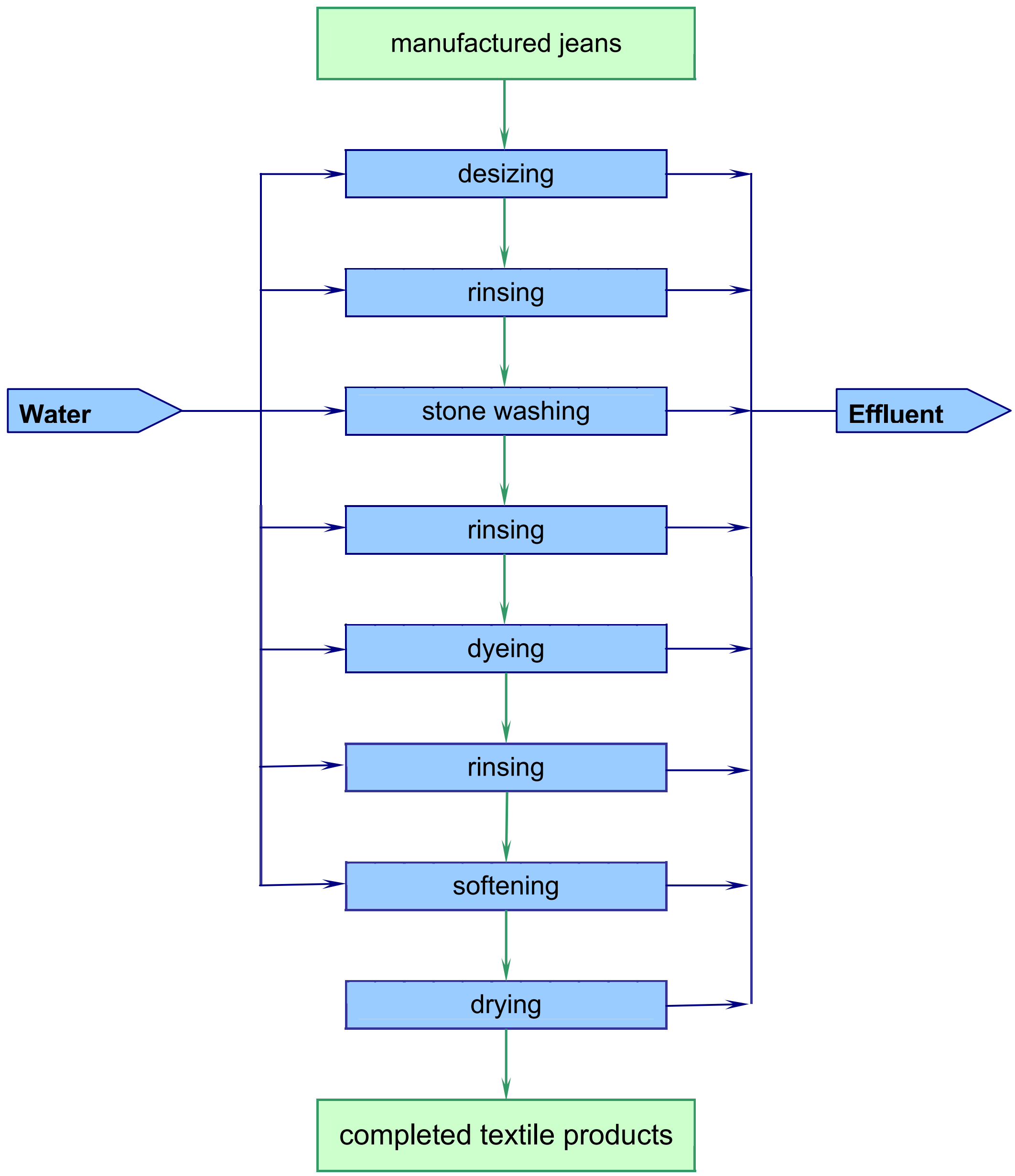


Figure 2.5 Process flow sheet for wet processing operations to produce dyed denim jeans as the final product.

2.4.11 Chemical additives

A number of additives (chemicals) are used in textile industries to give the final product certain properties such as washability, strength, brightness and colour-fastness (Jorgensen, 1979). The additives contribute to the variable character of textile effluents. According to Jones (1973), the textile industry uses a large amount of salt, ionic dyes, catalysts, detergents and bleaching agents, all of which add to the dissolved solids concentration of effluents. The effluents generated by the different production steps in a textile industry also have a high pH and temperature (Pala and Tokat, 2002). This is further stipulated by Nemerow (1971), in stating that textile effluents are generally coloured, highly alkaline and high in biochemical oxygen demand, suspended solids and temperature.

Despite over 100 years of process improvements, the stonewashing, dyeing and bleaching processes within the textile industry continue to utilise large volumes of clean water, exiting these industrial sites in large contaminated volumes that require proper handling. In addition, chemicals are added to perform a variety of functions during wet processing, resulting in large volumes of toxic effluent as a by-product. These large volumes of chemical-laden effluents from textile industries have become the focus of regulators worldwide as point sources of pollutants (Moore and Ausley, 2003).

2.5 THE ENVIRONMENTAL AND HEALTH IMPACTS OF TEXTILE EFFLUENTS

It is very easy to neglect or ignore the dependence of human life on the natural environment in an industrialised society, although the elemental and chemical composition of the earth, together with energy from the sun, constitutes all of the raw materials that support life (Nazaroff and Alvarez-Cohen, 2001). In the past, less attention has been given to the generation and release to the environment of contaminants from the extraction, conversion, supply and use of the earth's resources (Nazaroff and Alvarez-Cohen, 2001).

Effluents cause environmental problems and quality deterioration when they are discharged into receiving water bodies such as rivers, lakes, seas and groundwater. All industrial effluents affect, in some way, the normal life of a stream (Nemerow, 1971). These effects may render the stream unacceptable for its best usage and it is said to be polluted. Textile industry effluent is heavily charged with unconsumed dyes, surfactants and sometimes traces of metals (Hachem *et al.*, 2001). Each of these constituents presents a different hazard when the effluent is discharged into a water body, thus causing damage to the environment.

Dyes are usually present only in small amounts, but may be objectionable on account of their colour (Klein, 1957). However, the concentration of dyes makes the water not only aesthetically objectionable, but causes many water borne diseases. These include*, inter alia*, nausea, haemorrhage, ulceration of the skin and mucous membranes, dermatitis and severe irritation of the skin (Gupta *et al.*, 1990). These dyes also increase the biochemical oxygen demand (BOD) of the receiving waters, thereby reducing reoxygenation processes and this interferes with the biological activity in the body of water, especially hampering the growth of photoautotrophic organisms (Shukla *et al.*, 1992). The toxic effects of the dyes can be attributed to their anionic nature in the aquatic environment, as they may form complexes with positively charged metal ions such as $Mg^{2+}$and Ca^{2+}, which are essential for the growth and integrity of cells, and thus ultimately lead to a suppressed growth of these organisms (Nemerow, 1971).

The majority of the dyes used in the textile industry are resistant to biodegradation, photodegradation and even oxidising agents. Proper treatment of the dyes is essential because of their significant effect on photosynthetic activity due to reduced light penetration, and their toxicity to certain forms of aquatic life due to the presence of substituent metals and chlorine. Visible pollution retards the development of a community or area, since it discourages camping, boating, swimming and fishing; recreations indispensable to the vitality of a physically and mentally healthy community (Nemerow, 1971).

The inorganic materials in textile effluents render the water unsuitable for use because of excess concentrations of soluble salts contained (Souther, 1965). The organic compounds may also undergo a gradual chemical or biological change that removes oxygen from the water, resulting in septic condition characterised by odours, gases, floating solids and a generally disagreeable appearance (Souther, 1965). Textile processes such as bleaching involves the use of chemicals, which may cause negative effects on the ecosystem if effluents are not treated before discharge (Blomqvist, 1996). The chemicals of concern in textile effluents include sodium hydroxide, sodium hypochlorite, sodium sulphide, hydrochloric acid and reactive dyes (Blomqvist, 1996). The inorganic chemicals, even in extremely low concentrations may be poisonous to fish and other smaller aquatic microorganisms (Nemerow, 1971). Textile process effluents therefore require proper treatment before it can safely be disposed off into water bodies.

2.6 TEXTILE EFFLUENT TREATMENT

Due to the variance in nature of textile effluents, wastewater treatment plant operators are faced with difficult challenges of producing clean, non-toxic effluents. The pollutant features of textile effluents differ widely among various segments of the industry, and each type of waste presents a special treatment problem (Souther, 1965). The variable character of textile effluents is due to the different processes entailed in the industry, the variety of process chemicals used and the inconsistent rate of discharge flow (Nemerow, 1971).

It is natural that an industry may presume disposing off its effluent into a domestic sewer. This is, however, not possible due to the nature of some industrial effluent (Nemerow, 1971). Textile effluents are known to interfere with certain municipal wastewater treatment operations (Ramakrishna and Viraraghavan, 1997a). If there is no possibility of discharging its effluent to a municipal sewer, an industry must construct its own wastewater treatment facilities, which would include preliminary, primary, secondary and possibly tertiary treatment (Jones, 1973). The pollutant characteristics of wastes having readily definable effects on sewers and treatment plants can be classified as follows (Nemerow, 1971):

- biochemical oxygen demand (BOD);
- suspended solids;
- floating and coloured materials and
- other harmful constituents.

A typical wet processing facility at textile industries has a drainage system that transports effluent from the wet processing facility into a collection basin that equalises pH and flow (Moore and Ausley, 2003). The effluent flows from this collection (or equalisation) basin to chemical and biological wastewater treatment facilities. There is little segregation of waste streams within the textile manufacturing operations; therefore the effluent contains intermingled chemicals from the various steps of all the different processes. The chemical composition of the effluent is not the same day-to-day or even hour-to-hour, for it is completely dependant on the production process carried out (stonewashing, dyeing or bleaching) and thus the chemicals used (Moore and Ausley, 2003).

With the economical removal of dyes from effluents remaining a major concern, methods of treatment are continuously being modified and developed. Possible methods include chemical coagulation and also adsorption with, in water treatment, the most widely used method being adsorption on the surface of activated carbon (Pereira *et al.*, 2003). Activated carbons feasibly remove impurities occurring in water and coloured bodies. However, activated carbon is very costly, both to use and to regenerate. Another solution is the use of certain industrial and agricultural by-products as adsorbents for the removal of organics and inorganics from effluents (Robinson *et al.*, 2002). These are very low costing material and enhance overall waste management by using waste or by-products from other industries.

Iron (III) or Chromium (III) hydroxide is a waste generated in the treatment of Chromium (VI) bearing wastewaters in industry (Namasiyavan, 1994). This waste material can be used effectively as an adsorbent for the removal of dyes from textile effluents. Slag, which is a major product generated during steel making processes can also be used for the removal of dyes due to its nature of being porous with a large surface area and a wide particle size distribution (Ramakrishna and Viraraghavan, 1997b). However, these by-products normally have high concentrations of heavy metals making it environmentally undesirable.

Wheat straw, corn cobs and barley husks are some of the low cost agricultural substances that can act as adsorbents for the removal of dyes from textile effluents (Robinson *et al.*, 2002). The advantages of these agricultural substances are lower capital investment, simple designs and easier treatment operations.

2.7 TEXTILE EFFLUENT DISPOSAL

In the textile industry, there are two principal methods of effluent disposal. The effluent may either be discharged into watercourses or into sewers where they are purified by the local authority. Both options have stringent specifications. For discharge into watercourses, that is rivers, fairly strict limits are usually imposed, especially where the watercourses are used for supplies of drinking water or where they support fish. The limits are usually BOD 20 mg/l, suspended solids 30 mg/l and pH between 5 and 9 (Little, 1970). There are restrictions on the amounts of toxic chemicals and metals and a limit on temperature at the point of discharge. Due to these restrictions, it is a minimum requirement that the wastewater to be discharged undergo a fairly complete treatment before entering the watercourse. It should always be taken into consideration that water bodies can tolerate the input of certain wastes up to a certain extent without their quality deteriorating to a point that its uses are adversely affected (DWAF, 1995). This concept is referred to as a river's assimilative capacity.

The other method, which is discharging to sewers and purification by the local authority, however, has limitations and is sometimes not feasible (Little, 1970). It is often the case that the local sewage treatment works is small and the industry's effluent large in volume or high in strength to be accommodated in the local sewerage treatment works. If the volume and strength are not an issue, the limitations for discharge are based on the alkalinity or acidity of the discharge; and the concentrations of sulphide, chlorine and other substances that would give rise to danger to personnel, damage to drains or interference with the purification processes (Little, 1970). A charge is normally imposed based upon volume and composition of the discharged wastewater.

CHAPTER 3

Background to CGM Industrial (Pty) Ltd

3.1 INTRODUCTION

The company, CGM Industrial (Pty) Ltd (CGMI) consists of five factories involved in the production and wet processing of denim jeans. The five factories, which are CGM 1, CGM 2, Presitex, United and Kiota; are all situated in the Thetsane Industrial Area within close proximity to each other (see Figure 3.1). Production of jeans at each of the five factories involves ten main processes, four of which use vast quantities of water resulting in significant wastewater production (Figure 3.2). The ten main processes are divided into four sections of operational rooms; the cutting room, the sewing room, the wash room and the dispatch room. Although the wash room is the main concern of this dissertation due to the vast quantities of water used and disposed off, for completeness the other sections will also be briefly addressed.

Figure 3.1 The outline of GCM Industrial (Pty) Ltd.

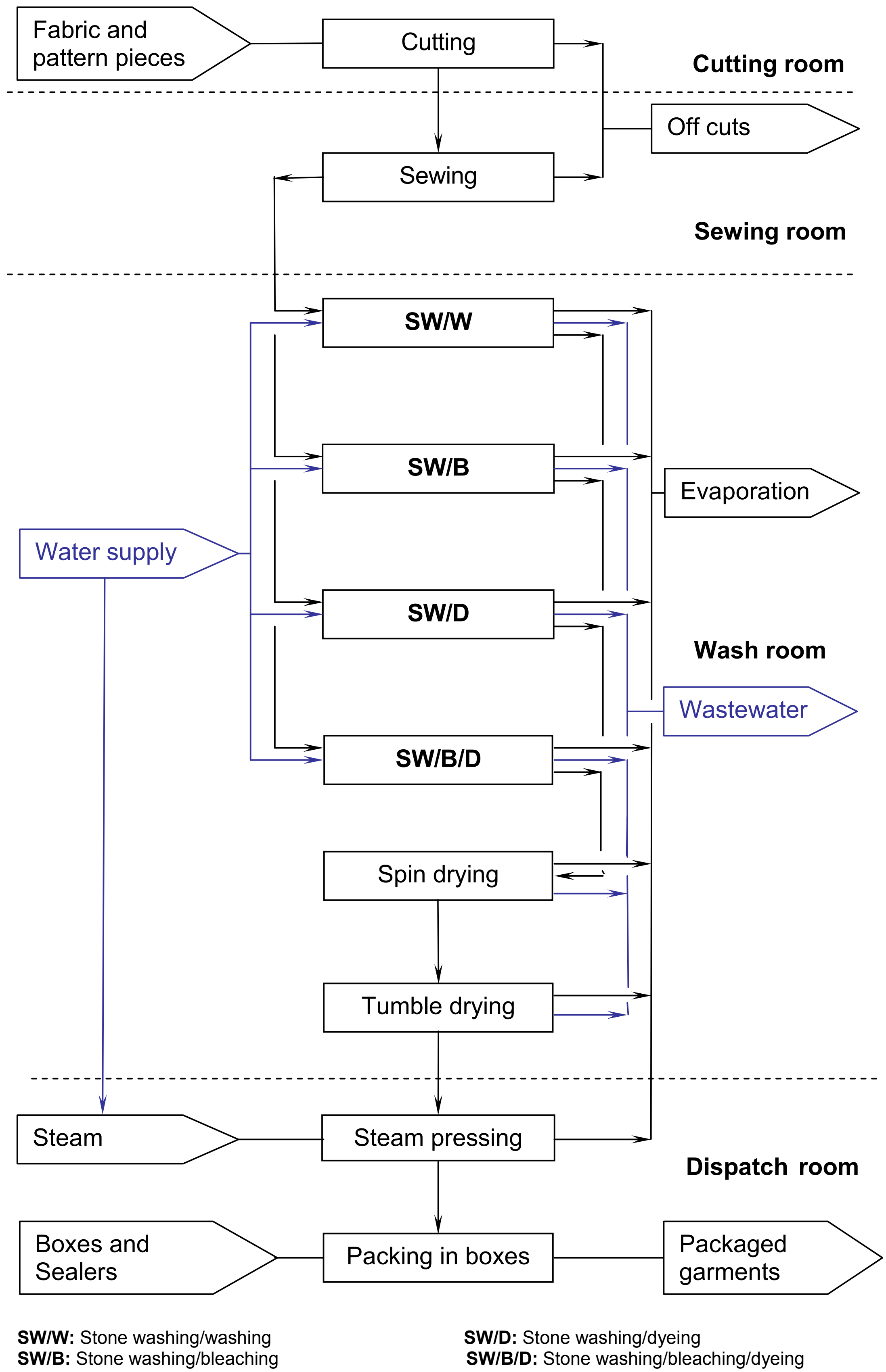


Figure 3.2 General flow diagram of a CGMI factory.

3.2 THE CUTTING ROOM

This is the first section in the production of garments at each of the five factories. First, a pattern maker at the industry draws a jeans pattern based upon a sample that was supplied by the customer or from a sheet with size specimens. There are usually 15 pieces that make up a standard pattern for a pair of standard 5 pocket jeans (Mokone, 2004). When the fabric is ready to be cut, the denim is laid out in layers on a cutting table. Up to 100 layers of denim are stacked and weights are put on top of it to hold the denim fabric in place, while it is being cut. A person in charge will then calculate the optimal fabric consumption by drawing all the pieces of the jeans pattern on a paper that is placed on top of the denim fabric. After drawing the cutting lines onto this paper, the separate parts of the jeans are cut with a textile cutting machine and each piece is then marked with it's size, using a piece of chalk so it won't show after washing. All of these pieces of cut denim are then put into bundles by size and are ready to proceed to the sewing room.

3.3 THE SEWING ROOM

In the sewing room (see Figure 3.3) the cut pieces are sewn together in multiple steps using different machines for each type of sewing stitch (namely, overcast, chain stitch, lock stitch and facing stitch). On average, it takes about 20 minutes and 12 steps to make one pair of jeans. There are different lines for sewing different pattern pieces together, for example, a line for sewing pockets on to the back part of a pair of jeans. The back part of the pair of jeans with the pocket sewn on is then passed on to the next line where it is sewn together with the front part. Then to another line until the whole garment is completed. A completed pair of jeans is then ready to proceed to the wash room.

Figure 3.3 Various sewing lines in a CGMI factory's sewing room.

3.4 THE WASH ROOM

The completed garments from the sewing room are put into trolleys and forwarded to the wash room. There are six main processes carried out in the wash room: four wet processing combinations, namely stone washing/washing, stone washing/bleaching, stone washing/dyeing and stone washing/bleaching/dyeing; as well as two drying processes, spin and tumble drying.

Each of the wet processing combinations at a CGMI factory produces an effluent with different characteristics due to the variety of chemicals used and the conditions under which the processes are carried out. Effluent characteristics are influenced by the quantities of water and chemicals used during denim wet processing, which are also dependant on the weight of the garments processed. Wet processing at CGMI takes place in washing machines, operated at three water levels - the minimum being 500 l, a medium level of 1 000 l and a maximum of 1 500 l. Each factory has two types of washing machines, automatic and manual types. The only difference between the two types are in their respective method for heating water, with the manual machines making use of steam for increasing the temperature and the automatic types using its built-in thermostats.

3.4.1 The stone washing/washing process combination

The stone washing/washing (SW/W) process combination is outlined in Figure 3.4. The first operation, desizing (see Section 2.4.1), is carried out at a temperature of 50^{o}C. A washing machine is filled up with water to a required water level depending on the load of garments to be washed. Ractase and Multiclean are then added to the machine to carry out the desizing operation. Ractase is an enzyme that decomposes the starch in the fabrics to a water soluble form and Multiclean is an antiback stain detergent (a chemical used to avoid redeposition of the blue indigo colour from the warp fibre onto the "white" weft fibre during the desizing operation; see Section 2.4.1). The desizing cycle runs for 13 minutes, after which the desizing water is discharged and the machine filled with clean water that has been recycled and stored in a reservoir for rinsing operations. Evaporation to the atmosphere also takes place during this operation.

The rinsing operation (see Section 2.4.2) takes 5 minutes, whereafter the water is discharged. Rinsing is followed by the stone washing operation (see Section 2.4.4) where water, together with pumice stones (see Figure 3.5), Felosan, BT 620 and soda ash; are added to a washing machine. Soda ash is used along with soaps, synthetic detergents and inorganic reagents to remove the non-cellulose impurities from the garments. Its operation is in this case aided by the addition of Felosan, which is a detergent and BT 620, an enzyme.

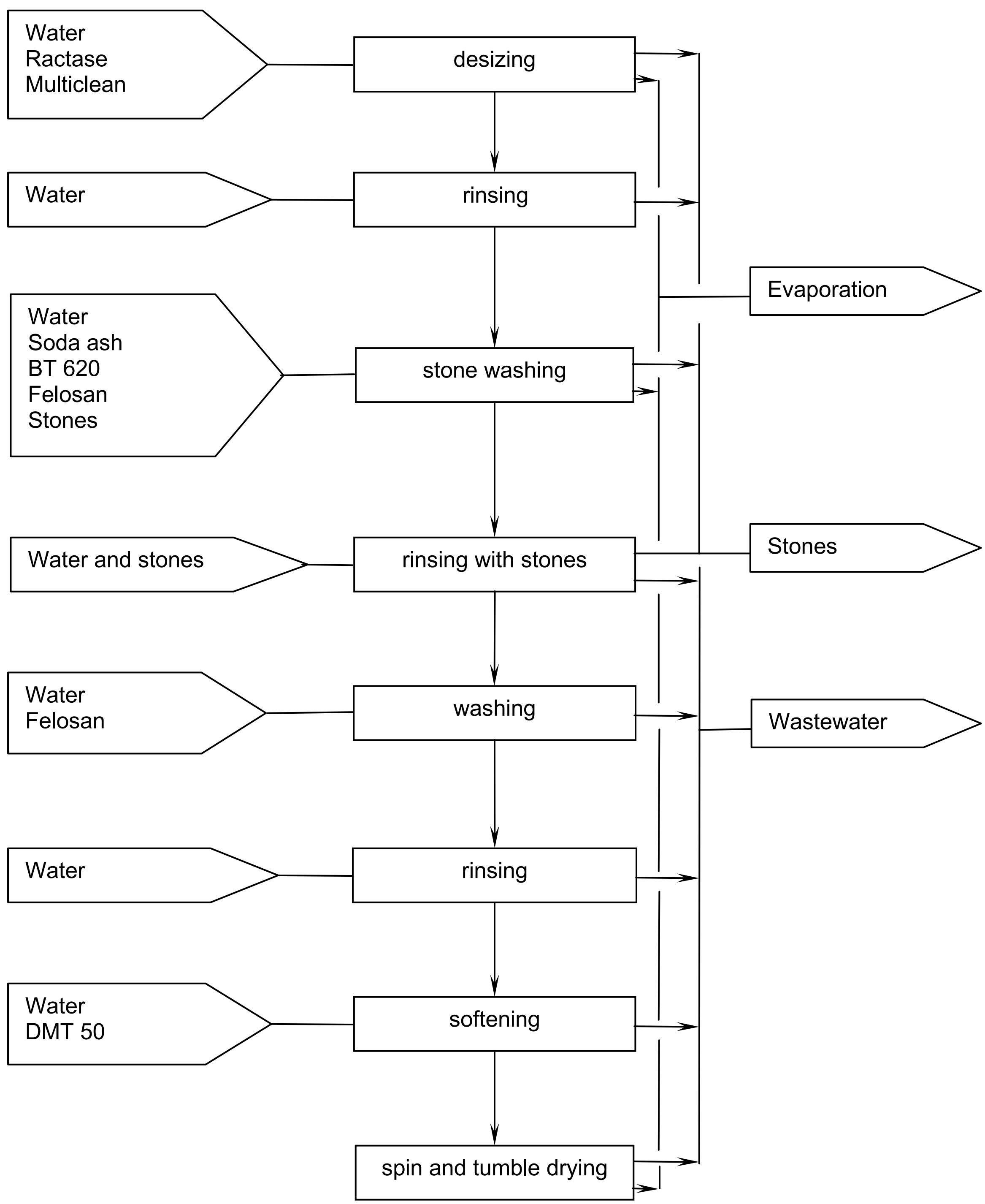


Figure 3.4 The stone washing/washing process combination at a CGMI factory.

The stone washing operation runs for 72 minutes at a temperature of 35°C. The water used during this operation is then discharged, but the stones are not removed from the machine. Water losses through evaporation take place during this operation. The stone washing operation is followed by another rinsing operation; which is done at room temperature for 5 minutes, along with the stones. The stones are then removed and the machine filled up with water for the next operation, which is the washing operation. Washing is carried out with water at room temperature, using Felosan as detergent. The washing operation (see Section 2.4.3) runs for 5 minutes, whereafter the water is discharged and the machine filled up with water for rinsing, which also runs for 5 minutes. After discharging the rinsing water, the machine is filled up with water for the softening operation (see Section 2.2.8). Using room temperature (± 20^{o}C) water and the fabric softener DMT 50, this operation takes 5 minutes. Finally, the garments are taken out of the machine to the spin and tumble drying processes (see Section 3.4.5), where additional evaporation and wastewater discharges take place.

Figure 3.5 Jeans and pumice stones in a washing machine, ready to be stone washed.

The quantities of water and chemicals used during the stonewashing/washing process operations depend on the style and weight of the load to be processed. Table 3.1 outlines typical quantities for the chemicals and water used at a CGMI factory for a particular style with a weight load of 70 kg.

Table 3.1 Quantities of chemicals and water used during the stone washing/washing process combination.

Operation	Inputs	Quantities	Water temperature	Operation time (minutes)
Desizing	water Ractase Multiclean	500 l 500 ml 500 ml	50°C	13
Rinsing	water	1 500 l	± 20°C	5
Stone washing	water stones BT 620 Felosan soda ash	500 l 3 drums 1 000 g 500 ml 50 g	35°C	72
Rinsing	water stones	1 000 l 3 drums	± 20°C	5
Washing	water Felosan	500 l 500 ml	± 20°C	5
Rinsing	water	1 500 l	± 20°C	5
Softening	water DMT 50	500 l 1 000 ml	± 20°C	5
Total for relevant process		6 000 l	-	110

3.4.2 The stonewashing/bleaching process combination

Stone washing/bleaching (SW/B) is the second water intensive process combination at CGMI (see Figure 3.6). Depending on the style required, sometimes garments need to be bleached to a shade requested by a relevant client.

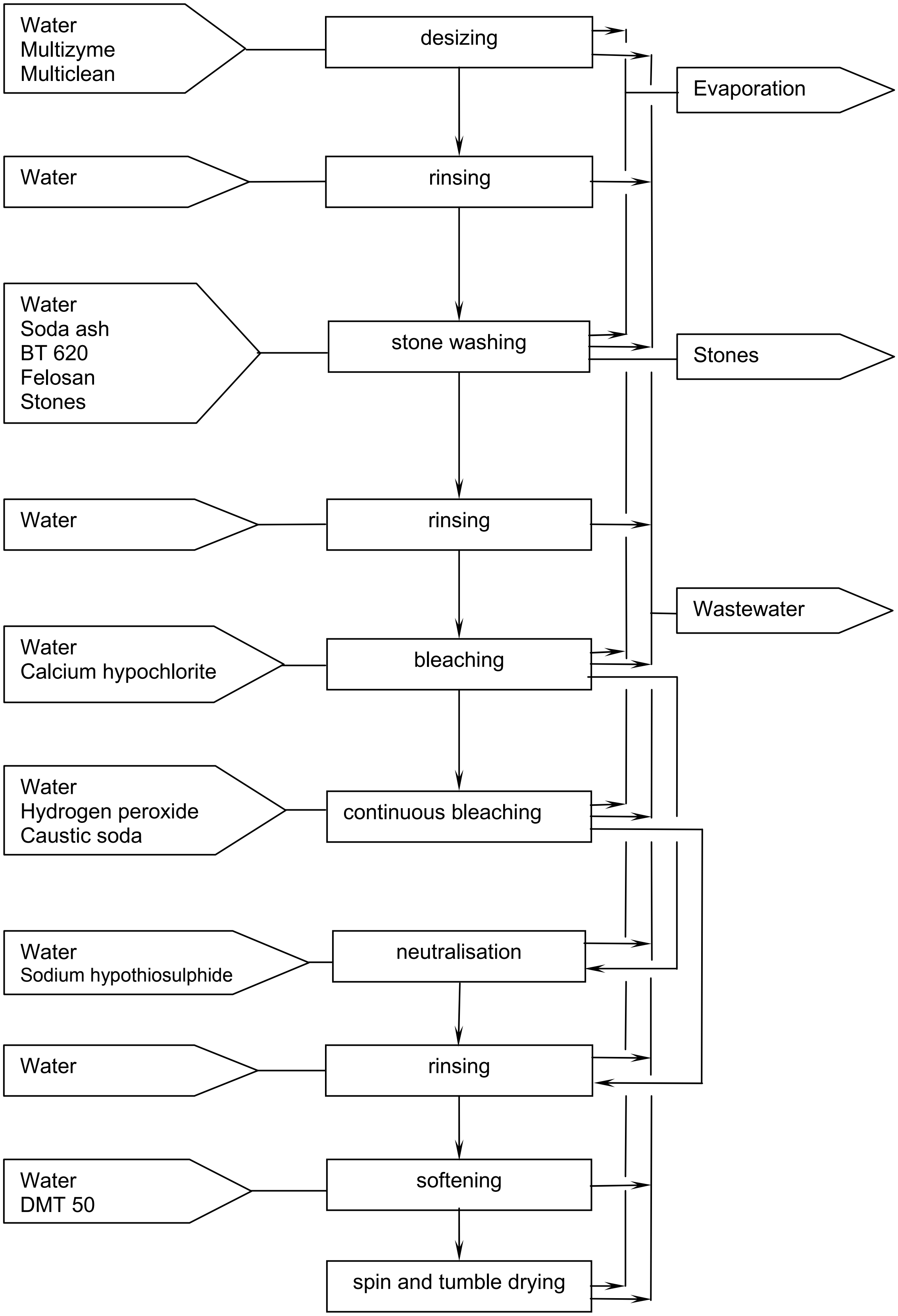


Figure 3.6 The stone washing/bleaching process combination at a CGMI factory.

The first three operations of the stone washing/bleaching process combination (desizing, rinsing and stone washing) are similar to that of the stone washing/washing process combination. What differs is the enzyme used in the desizing operation. In the stone washing/bleaching process combination, Multizyme is used instead of Ractase. The temperatures and the time intervals for the operations also differ (see Table 3.2). After the second rinse with water, the water is discharged and the bath is filled with water for the bleaching operation (see Section 2.4.5). Calcium hypochlorite is the bleach used at CGMI for bleaching operations. The operation runs for 5 minutes at a temperature of 60^{o}C. The water is then discharged and the machine filled with water for the next operation, which is neutralisation (see Section 2.4.6). Sodium hypothiosulphide is used to neutralise the reaction of the bleaching reagent. This operation takes 5 minutes with water at room temperature (± 20^{o}C).

When the shade of garments obtained after bleaching is not as light as required, the garments will undergo another bleaching operation to be lightened to the required shade. The operation is referred to as continuous bleaching. In continuous bleaching, hydrogen peroxide is used together with caustic soda. The operation runs for 10 minutes at 60^{o}C. (Calcium hypochlorite may also be used, depending on the decision of the personnel in charge.) The load of garments from the hydrogen peroxide bleaching need not be neutralised.

After neutralisation, the garments are rinsed and softened, similarly as for the SW/W process combination. After the softening operation the garments are put into other machines for spin and tumble drying, where some of the water absorbed by the garments is lost as wastewater and some through evaporation (see Section 3.4.5).

The quantities of the chemicals and water in the SW/B process combination are determined by the weight of the load to be processed. With the operational running times always the same, only the amount of water and chemicals used varies according to the relevant weight of garments. The quantities involved in the SW/B process combination outlined in Table 3.2 are for a load weighing 70 kg.

Table 3.2 Quantities of chemicals and water used for the stone washing/ bleaching process combination at a CGMI factory.

Operation	Inputs	Quantities	Water temperature	Operation time (minutes)
Desizing	water Multizyme Multiclean	500 l 500 ml 500 ml	60°C	10
Rinsing	water	1 500 l	± 20°C	5
Stone washing	water stones BT 620 Felosan	500 l 2 drums 800 g 500 ml	35°C	50
Rinsing	water	1 500 l	± 20°C	5
Bleaching	water calcium hypochlorite	1 500 l 5 000 ml	60°C	5
Neutralisation	water sodium hypothiosulphide	1 500 l 3 kg	± 20°C	10
Continuous bleaching	water hydrogen peroxide caustic soda	500 l 1 000 ml 1 000 ml	60°C	10
Rinsing	water	1 500 l	± 20°C	5
Softening	water DMT 50	500 l 1 000 ml	± 20°C	5
Total for relevant process		9 500 l	-	105

3.4.3 The stone washing/dyeing process combination

The first four operations of the stone washing/dyeing (SW/D) process combination (desizing, rinsing, stone washing and rinsing with stones) are the same as for the stone washing/washing process combination (see Figure 3.7). In the stone washing/dyeing process combination a second rinse follows after rinsing with stones, before the garments undergo dyeing.

In the dyeing operation (see Section 4.2.7), the load (of garments) is spun in water, with the appropriate quantities of dyes (see Table 3.3) for such a load, at 60^{o}C for 2 minutes. After 2 minutes, sodium chloride is added to the same load under the same conditions (same water, dyes and temperature) and spun for a further 3 minutes. The dyeing water is then discharged and the washing machine filled with water for rinsing. After rinsing at room temperature (± 20^{o}C) for 3 minutes, a fabric softener (DMT 50) is added to the same water and the load is spun for 5 more minutes. The water is then discharged and the garments forwarded for spin and tumble drying, with entailed wastewater discharges and evaporation losses (see Section 3.4.5).

Table 3.3 Types of dyes used at CGMI factories.

• Brown GGL	• Black VSF	• Yellow 4GL
• Brown 8RL	• Blue	• Red
• Orange GGLN	• Grey CGLL	• Violet

The quantities for water and chemicals (including dyes) in the stone washing/dyeing process are also determined by the weight of the load to be dyed, as well as the required/requested style. The quantities in Table 3.4 are for a load of 70 kg, dyed in a brown colour.

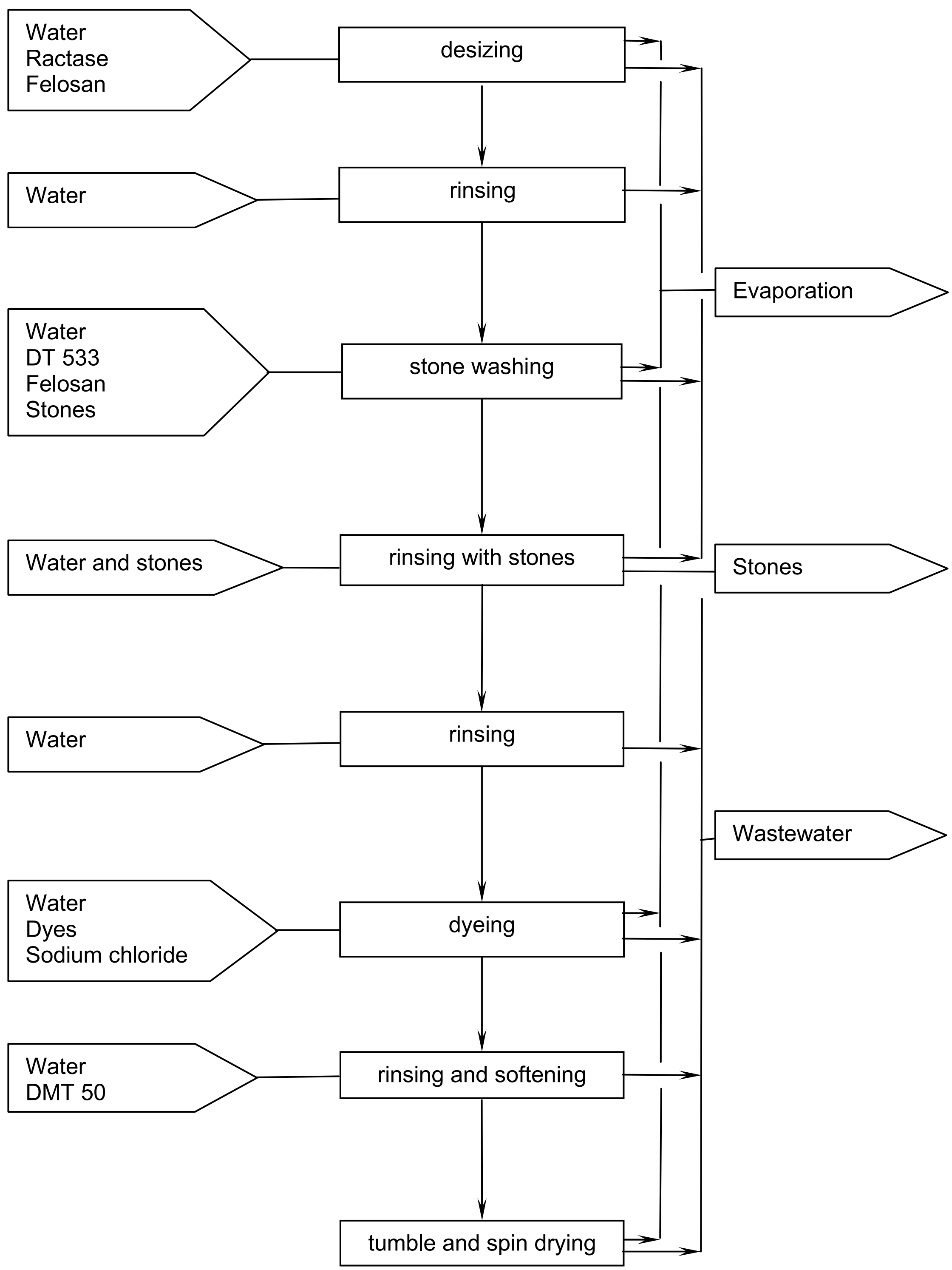


Figure 3.7 The stone washing/dyeing process combination at a CGMI factory.

Table 3.4 Quantities of chemicals and water used for the stone washing/ dyeing process combination at a CGMI factory.

Operation	Inputs	Quantities	Water temperature	Operation time (minutes)
Desizing	water Ractase Felosan	500 l 500 ml 500 ml	60°C	10
Rinsing	water	1 500 l	± 20°C	5
Stone washing	water stones DT 533 Felosan	500 l 2 drums 500 g 500 ml	35°C	55
Rinsing with stones	water stones	1 500 l 2 drums	± 20°C	3
Rinsing	water	1 500 l	± 20°C	5
Dyeing	water Brown 8RL Brown GGL	1 000 l 6,5 g 12 g	60°C	2
	sodium chloride	1 000 g	60°C	3
(Rinsing and) Softening	water DMT 50	1 000 l 500 ml	± 20°C	3 5
Total for relevant process		7 500 l	-	90

3.4.4 The stonewashing/bleaching/dyeing process combination

For the stone washing/bleaching/dyeing process combination (SW/B/D), the first seven operations (desizing, rinsing, stone washing, rinsing, bleaching, neutralisation and rinsing) are similar to those of the stone washing/bleaching process combination (see Figure 3.8). The difference is that for the desizing operation, Felosan is used instead of Multiclean. The operational conditions for the stone washing operation in this process combination also differ to that of stone washing/bleaching process combination. In SW/B/D process combination, the load is spun for 40 minutes at 56^{o}C (instead of 50 minutes at 35^{o}C for the SW/B process combination), and Neozyme and one drum of stones are used instead of BT 620 and 2 drums of stones.

After neutralisation and rinsing, the relevant washing machine is filled with 500 l of water for the dyeing operation (see Section 2.4.7). The load is spun in the water with the appropriate quantities of dyes for such a load, at 60^{o}C for 2 minutes. After 2 minutes, sodium chloride is added to the same load under the same conditions (same water, dyes and temperature) and spun for another 3 minutes. The dyeing water is then discharged and the machine filled with water for the softening operation. A fabric softener (DMT 50) is added to the water and the load is spun for 5 minutes. After discharge of the rinse/softening water, the garments are forwarded for spin and tumble drying, where additional discharges and evaporation takes place (see Section 3.4.5).

The quantities of chemicals and water used during the stone washing/bleaching/dyeing process operations depend on the style and weight of the load to be processed. Table 3.5 outlines typical quantities for the chemicals and water used at a CGMI factory for a particular style with a weight load of 70 kg.

3.4.5 Spin drying and tumble drying

Spin drying and tumble drying are the last processes entailed in the wash room of a CGMI factory. All the garments that have undergone any one of the four process combinations are spin and tumble dried. Spin drying is used to drain off excess water from the garments and tumble drying for drying the spin dried garments. Both processes are done in drying machines (see Figure 3.9). In spin drying a certain amount of water is discharged, contributing to the factory's wastewater production, as well as steam; whereas tumble drying contributes solely to the steam production (evaporation losses) at a factory.

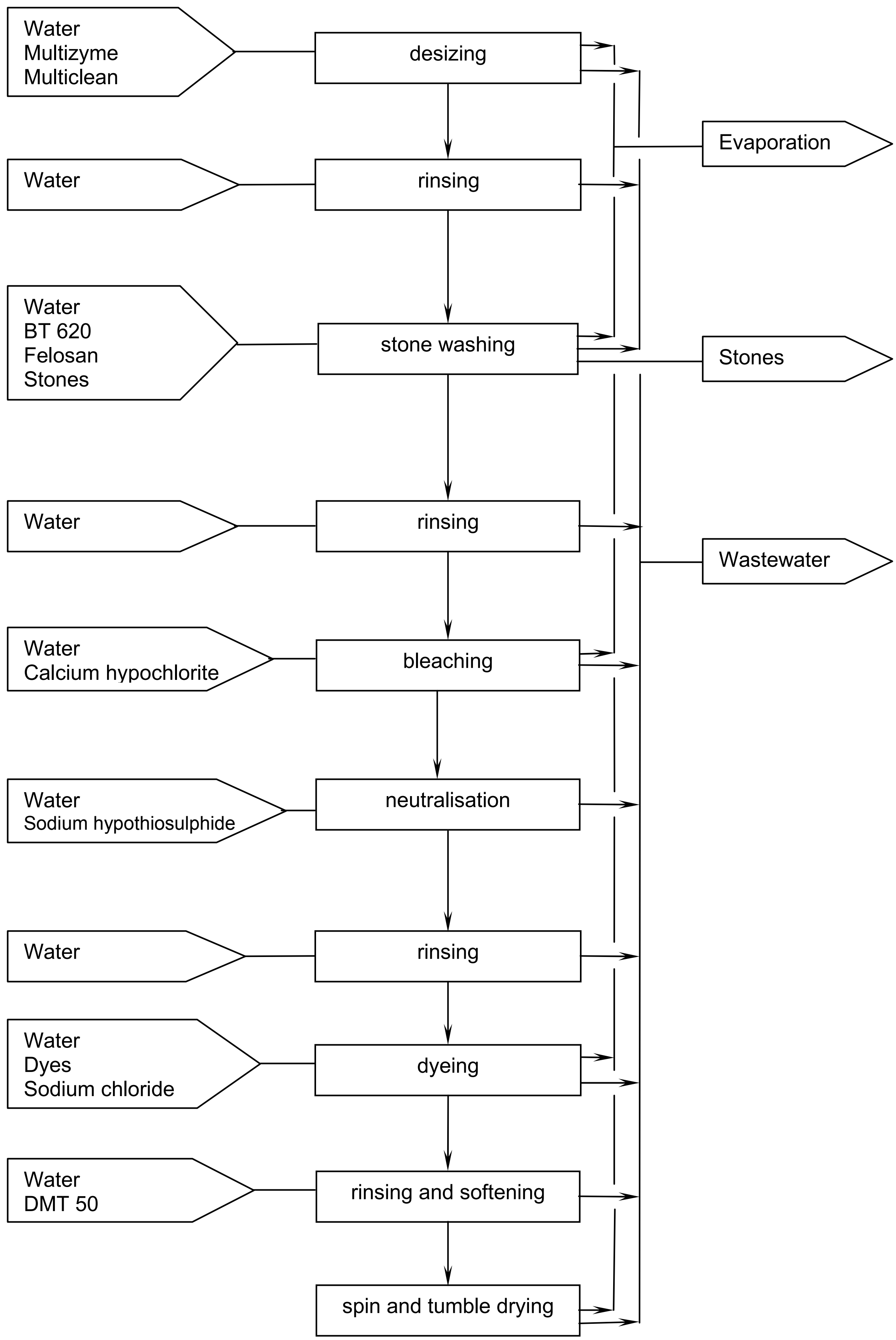


Figure 3.8 The stonewashing/bleaching/dyeing process combination at a CGMI factory.

Table 3.5 Quantities of chemicals and water used for the stone washing/bleaching/dyeing process combination at a CGMI factory.

Operation	Inputs	Quantities	Water temperature	Operation time (minutes)
Desizing	water Multizyme Felosan	500 l 500 ml 500 ml	60°C	10
Rinsing	water	1 500 l	± 20°C	5
Stone washing	water stones Neozyme Felosan	500 l 1 drum 600 g 500 ml	56°C	40
Rinsing	water	1500 l	± 20°C	5
Bleaching	water calcium hypochlorite	1 500 l 3 000 ml	60°C	5
Neutralisation	water sodium- hypothiosulphide	1 500 l 3 kg	± 20°C	5
Rinsing	water	1 500 l	± 20°C	5
Dyeing	water Orange Brown GGL	500 l 6,5 g 12 g	60°C	2
	sodium chloride	500 g	60°C	3
(Rinsing and) Softening	water DMT 50	1 000 l 500 ml	±20°C	3 5
Total for relevant process		10 000 l	-	88

Figure 3.9 Machines used for spin and tumble drying processes at CGMI factories (the silver machines to the right are for spin drying and the blue machines at the back for tumble drying).

3.4.6 Checking

During each of the four process combinations, garments (jeans) are removed from a load after certain operations and checked for the required shade of a garment. The process involves randomly selecting two jeans out of a load that is being processed (after completion of the actual operation), and placing them in a 50 l drum containing water for checking of the shade. The checking is done against a wetted sample from a client to visually match the sample to the load. The checking operation takes place during the following instances:

- for the stone washing/washing process combination, checking is done after the stone washing operation;
- for the stone washing/bleaching process combination, checking is done after the stone washing and after the neutralisation operations;

- for the stone washing/dyeing process combination, checking is done after the stone washing operation and after the dyeing operation; and
- for the stone washing/bleaching/dyeing process combination, checking is done after each of the stone washing, neutralisation and dyeing operations

3.5 THE DISPATCH ROOM

From the wash room dried garments proceed to the dispatch room (see Figure 3.10), where final quality inspection takes place and paper tags and labels are placed or attached. A denim garment is inspected for faults, loose threads are cut and the button(s) and rivets are placed using a special type of press. A typical pair of jeans will have an imitation leather label on the waistband, a small brand label, a wash label with care instructions and size, and a hangtag or back pocket carton label. The garments are then steam pressed using steam irons. Finally, the jeans are placed in a polybag with proper warning text and packed in a box or bag depending on the destination country. All these operations are done manually. The sealed boxes are stored in the store room ready for delivery to the customer.

3.6 WATER MANAGEMENT AND TREATMENT AT CGM INDUSTRIAL (PTY) LTD

The water used at CGMI is supplied by the Water And Sewerage Authority (WASA), which is the local body responsible for the management of potable water supply and wastewater collection, conveyance and treatment in the Maseru area. CGMI has a storage dam (capacity 8 Ml) for storing water from WASA for production purposes at the premises (see Figure 3.11). The storage is sufficient for a period in excess of one day, ensuring continued production during instances of water scarcity and/or interrupted water supply.

Figure 3.10 Finishing off garments for packaging in the dispatch room.

Figure 3.11 Storage dam for water supply at CGMI.

The water obtained from WASA is used for either wet processing, drinking water for the employees, or for supplementing water required for ablution services (which mostly make use of recycled water from the waste water treatment plant). Based on the relevant processes and activities, there are three categories of water that leaves the industry, namely evaporation (during wet processing and drying), ablution water (to the WASA sewerage system) and effluent from the wastewater treatment plant (to the natural water course).

CGMI has in the past been discharging its effluent into WASA's treatment works, which evoked their permit because the effluent was not pre-treated and did not meet the disposal requirements. This forced the company to build its own treatment facilities, situated a few metres from the five industries (Figure 3.1).

The wastewater generated from the different wet processes within the industry is not segregated. From the washing machines, effluent flows into drains across and along factory floors (see Figure 3.12). These drains join into one large outlet that leaves each factory's building (see Figure 3.13). The outlet from each of the five factories joins into one drain as it reaches the new wastewater treatment plant (see Figure 3.14).

Figure 3.12 Drains along and across the floor at the CGM 1 factory.

Figure 3.13 Effluent outlet from a CGMI factory (CGM 1).

Figure 3.14 Wastewater from all five factories as it reaches the wastewater treatment plant.

The wastewater treatment plant at CGMI consists of seven different stages (see Figure 3.15). During the first stage, pumice stones (used in the stone washing operation), scourings from cloth and any form of grit are collected using screens.

Due to the variable character of textile wastewaters (as a result of the different processes and chemicals used, and the inconsistent rate of discharge flows), equalisation and aeration take place during the second stage (Figure 3.16). This is to minimise variation and shock loadings to succeeding treatment stages.

During the third stage neutralisation of the alkaline textile wastewater takes place to balance the pH. The neutralised wastewater is pumped to the next process unit for flocculation, the fourth stage of the wastewater treatment plant. Polymers used during flocculation include polyacrylamide, polyaluminium chloride and methylene.

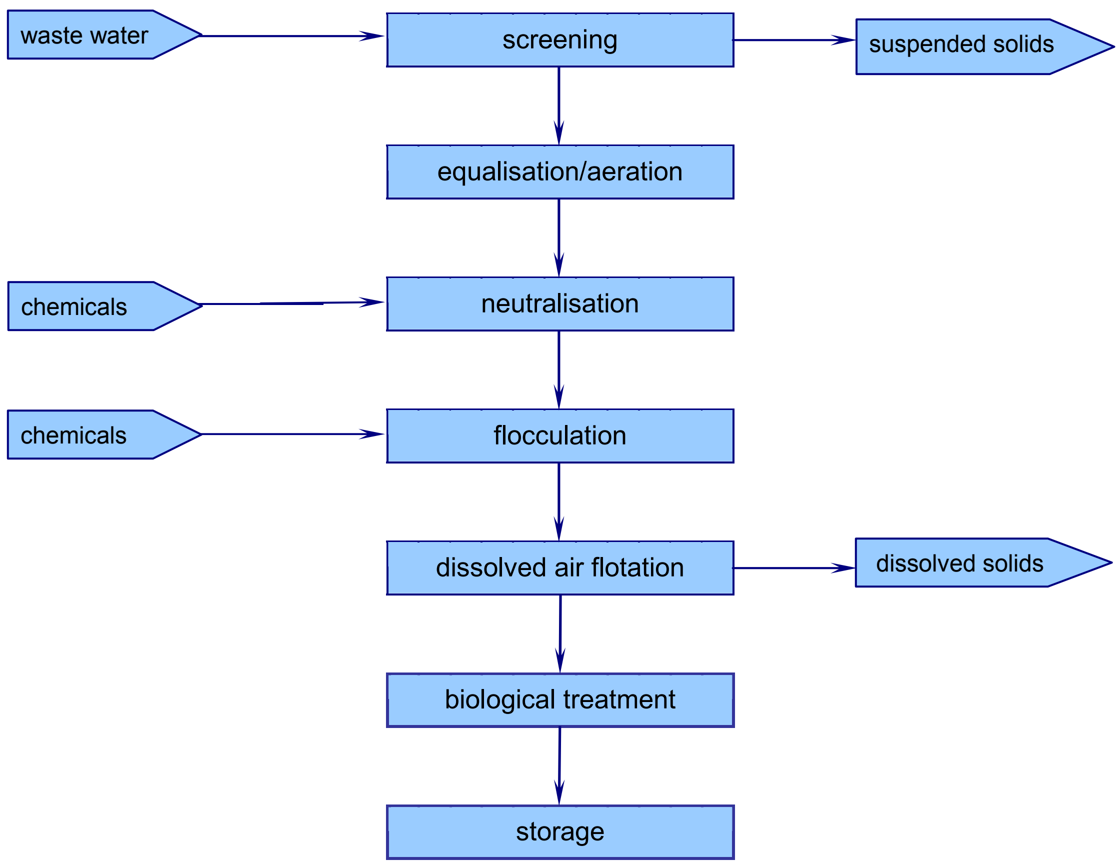


Figure 3.15 Process flow sheet for wastewater treatment plant at CGMI.

The next stage of treatment involves the removal of colour in the dissolved air flotation (DAF) unit (Figure 3.17). Air is pumped from below to bring flocculated dyes and other particles to the surface of the basin, from where the particles, and thus colour are removed from the water.

Figure 3.16 Equalisation basin with aeration.

Figure 3.17 The dissolved air flotation unit at CGMI for dye particle removal.

Biological treatment forms the sixth stage in the treatment of CGMI wastewater. This stage consists of five vessels containing special biological activated carbon filters for the breaking down and adsorption of particles in the wastewater (Figure 3.18). The filters provide a place on which the microorganisms that break down the particles in the wastewater grow, as well as an adsorption media for the broken down particles. Oxygen (through aeration) is a major requirement for providing optimum conditions for the microorganism growth enhanced particle absorption.

Figure 3.18 The biological treatment basins.

The final stage of the plant involves storage of the treated water (Figure 3.19) for reuse at processes that do not require water of high quality, such as ordinary washing and rinsing (processes such as dyeing and bleaching require water of high quality and therefore uses water supplied by WASA). Water in excess of the storage capacity is discharged into a nearby stream, which eventually reaches the Mohokare River.

In addition, the capacity of CGMI's wastewater treatment plant at times cannot accommodate all the water from the five factories and additional discharge of untreated wastewater still takes place (Figure 3.20). It is therefore evident that water management for the industry needs to be reviewed to ensure sustainable water resource management.

Figure 3.19 The storage dam at the treatment plant for water to be reused at the industry.

Figure 3.20 The results of equalisation basin overflow (pollution).

CHAPTER 4

Water balance for the CGM 1 factory

4.1 INTRODUCTION

Water at CGM Industrial Pty (Ltd) (CGMI) is used for several purposes; including drinking, personal hygiene (washing dishes and hands) and for the main focus of this dissertation, wet processing used during the manufacturing of garments (jeans). In all five factories (CGM 1, CGM2, Presitex, United and Kiota), the same processes are carried out, represented in the overall water balance for CGMI in Figure 4.1; with a simplified water balance for CGM1 presented in Figure 4.2.

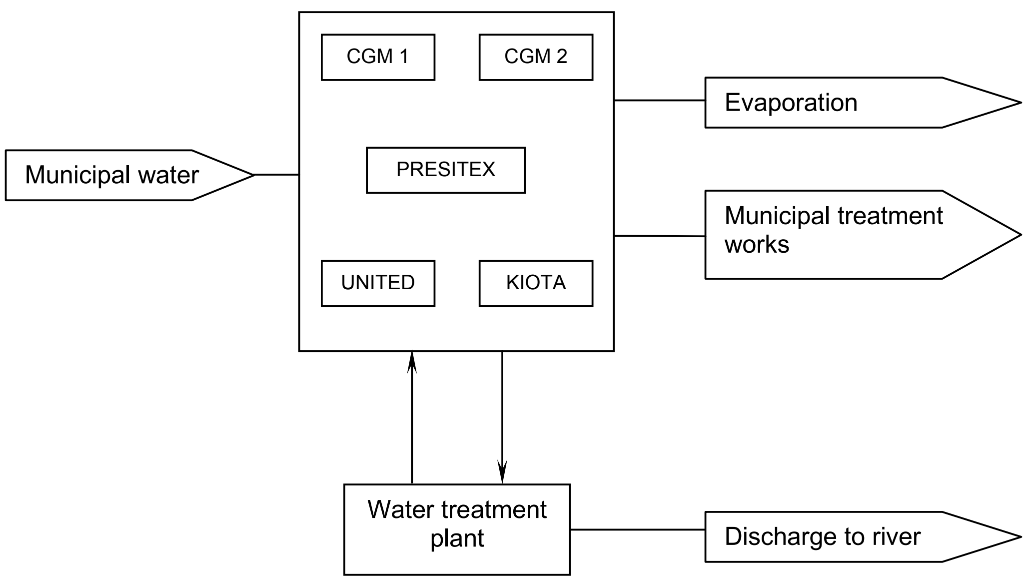
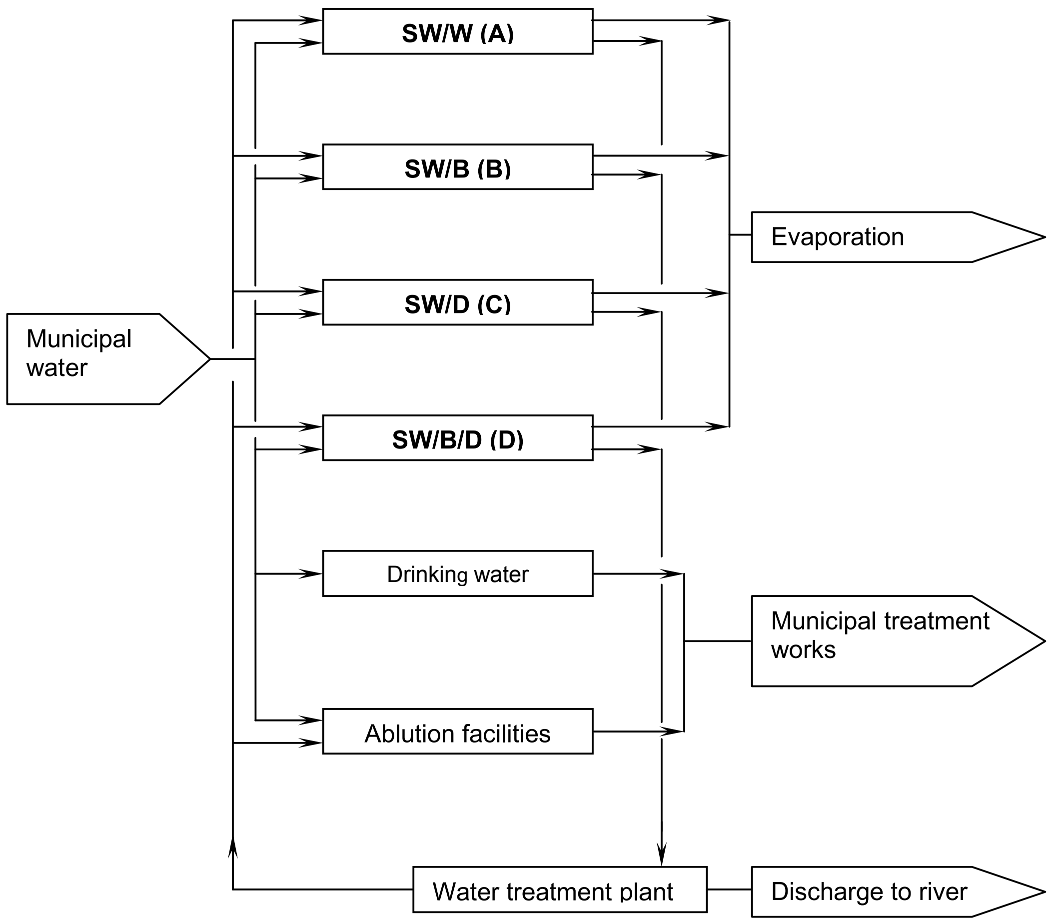


Figure 4.1 Overall water balance for CGM Industrial Pty (Ltd).



SW/W (A): stone washing/washing (Process A) **SW/D (C):** stone washing/dyeing (Process C)
SW/B (B): stone washing/bleaching (Process B) **SW/B/D (D):** stone washing/bleaching/dyeing (Process D)

Figure 4.2 Simplified water balance for processes entailed at CGM 1.

The simplified water balance for CGM 1 (Figure 4.2) is representative of each of the five CGMI factories. Municipal water enters CGM 1 and is used in the wash room for the four main wet processes, namely stone washing/washing, stone washing/bleaching, stone washing/dyeing, and stone washing/ bleaching/dyeing; as well as for cleaning of floors. Municipal water is also used for drinking water and to augment ablution facilities' water requirements.

The effluent generated from CGM 1 consists of the wastewater from the wash room processes, and drinking and ablution facilities. The effluent from the wash room processes is discharged to the water treatment plant; where it is treated, a portion recycled back to the factory and the remainder discharged to the river. Water from the drinking and ablution facilities is discharged into WASA's (municipal) sewerage system. Finally, water is also lost from the factory through evaporation, mostly from the drying processes.

4.2 OPERATION AND DATA COLLECTION

The CGM 1 factory has 37 washing machines in the wash room, which operate simultaneously for 24 hours a day. The wet processes are carried out in batches that are referred to as loads. The amount of effluent discharged from the wash room depends on the number of loads processed per day. The average loads of garments processed per day, six days a week, are between 6 – 8 loads per machine (Potlaki, 2004); resulting in 222 – 296 loads per day. The number of loads, however, is also dependant on the following factors (Potlaki, 2004):

- The style of jeans requested by a client - influences the process combination to be carried out. The time taken for the completion of each process differs and will thus determine the number of loads per day (see Section 3.4). The stone washing/washing process on average takes 110 minutes (± 15 minutes for checking and machine operation); the stone washing/bleaching 100 minutes (± 20 minutes); stone washing/dyeing 90 minutes (± 20 minutes) and the stone washing/bleaching/dyeing process an average of 90 minutes (± 25 minutes).
- The number of machines in operation for a particular day - this is influenced by breakages and machine repairs, which might delay production.
- Water availability - sometimes due to water scarcity production and subsequent effluent discharges are reduced.
- The absence of the person in charge of a particular machine - the machine will not be in operation for some period and thus no water usage or wastewater discharges.

The number of loads per day, determined during the period of data collection, for all four process combinations entailed at CGM 1 is outlined in Table 4.1.

Table 4.1 The number of loads processed at CGM 1 during the period of data collection, 1 December 2004 to 15 January 2005.

Date	SW/W	SW/B	SW/D	SW/B/D	Number of machines in operation
01/12/04	11	-	26	-	7
02/12/04	1	2	45	-	9
03/12/04	14	12	73	-	18
04/12/04	-	-	32	-	8
06/12/04	4	-	64	87	27
07/12/04	-	-	90	5	19
08/12/04	-	-	65	108	29
09/12/04	-	-	96	-	16
10/12/04	-	-	94	-	16
11/12/04	-	-	31	44	17
13/12/04	-	-	94	-	17
14/12/04	-	16	90	-	21
03/01/05	6	-	20		8
04/01/05	-	-	16	-	4
05/01/05	-	-	61	-	14
06/01/05	-	-	74	-	15
07/01/05	-	-	77	-	15
08/01/05	-	-	66	-	15
10/01/05	8	-	54	8	16
11/01/05	8	-	86	-	16
12/01/05	4	-	163	-	27
13/01/05	-	-	167	1	28
14/01/05	-	-	21	161	30
15/01/05	-	-	30	160	30
TOTAL	**56**	**30**	**1 635**	**574**	

Depending on the style and size of the garments to be processed, a particular load can consist of a different number of garments. For smaller size garments there would be a lot more pieces of garments than a bigger size of the same style. For example, a particular load can have 150 garments that weigh 70 kg and for the next load 220 garments, which still weigh 70 kg. At CGMI the weight of the load to be processed is kept standard at 70 kg, although the garments may vary in number. For this dissertation a single load of 120 garments weighing 70 kg was used for all calculations.

Each style manufactured has a process flow sheet indicating the quantities of water used, the amounts of chemicals used, as well as the running time for the process (see Tables 3.1, 3.2, 3.4 and 3.5). From the process flow sheet, the amount of water per load can be determined based on the relevant process combinations required for a particular style. The amount of water for the four different water intensive process combinations differ due to the operations entailed in each.

Water used in the stone washing/washing process (Process A) is for:

- desizing,
- rinsing (carried out after each operation),
- stone washing,
- softening, and
- checking.

Water used in the stone washing/bleaching process (Process B) is for:

- desizing,
- rinsing (carried out after each operation),
- stone washing,
- bleaching,
- neutralisation,
- softening, and
- checking.

Water used in the stone washing/dyeing process (Process C) is for:

- desizing,
- rinsing (carried out after each operation),
- stone washing,
- dyeing,
- softening, and
- checking.

Water used in the stone washing/bleaching/dyeing process (Process D) is for:

- desizing,
- rinsing (carried out after each operation),
- stone washing,
- bleaching and continuous bleaching,

- neutralising,
- dyeing,
- softening, and
- checking.

Some of the operations within the processes require high temperature conditions that are acquired through the use of steam. During the period of data collection, 217 000 litres of water were used for steam production. (Steam is produced on site using a boiler on the premises). The four different water intensive processes have different operations which require steam and these are outlined below:

Stone washing/washing (Process A):

- desizing operation and
- stone washing operation.

Stone washing/bleaching (Process B):

- desizing operation,
- stone washing operation,
- bleaching operation and
- continuous bleaching operation.

Stone washing/dyeing (Process C):

- desizing operation,
- stone washing operation and
- dyeing operation.

Stone washing/bleaching/dyeing (Process D):

- desizing operation,
- stone washing operation,
- bleaching operation and
- dyeing operation.

4.3 DATA ANALYSES AND PROVISIONAL ASSUMPTIONS

4.3.1 Cleaning water and checking water

The water used in the wash room for the wet processing operations is measured and controlled, except for the water used in cleaning floors and checking water. This water is supplied through a hosepipe to the place where required. Cleaning water is used for clearing stones on the floor and washing off foam and any other form of dirt from the wash room floors. Water used for checking is put into 50 l drums, which sometimes overflow, and the amount not measured. For this dissertation, checking water will be approximated as 50 l per checking operation.

4.3.2 Water used for steam

No specific data was available for steam use per operation at CGM 1. The total number of operations that used steam during the period of data collection was 7 433 (112 + 4 905 + 120 + 2 296, see Table 4.2). From Section 4.2 a total of 217 000 litres water was used for the generation of steam during the period of data collection. An average of 29,2 l water (217 000 l/7 433 operations) per steam operation will therefore be used for calculation purposes in this dissertation.

Table 4.2 The number of operations that used steam at CGM 1 during the period of 1 December 2004 to 15 January 2005.

Process	Steam using operations	No of loads processed	Total number of operations that used steam
Process A	2	56	112
Process B	4	30	120
Process C	3	1 635	4 905
Process D	4	574	2 296

4.3.3 Water absorbed by garments

The garments being processed will absorb some of the water used. To determine the absorption capacity of denim material, five garments (pairs of jeans from a load of 120 garments) were reweighed after wet processing and an absorption capacity calculated as follows:

Before processing:
120 garments weighing 70 kg implies one piece weighs 0,58 kg.

After processing:
Five garments selected after wet processing weighed 7,2 kg, implying one garment weighed 1,44 kg; thus absorbing 0,86 kg water/garment. Assuming that the garments will only absorb water to a certain maximum capacity; for this dissertation this implies that a load of 120 garments weighing 70 kg before processing, will absorb 120 x 0,86 = 103,20 kg of water per load processed.

The water absorbed by the garments will either be lost to wastewater during spin and tumble drying, lost to evaporation during spin and tumble drying, or be contained within the garments for final processing. For this dissertation it is conservatively assumed that all absorbed water is lost to wastewater.

4.3.4 Evaporation

Due to lack of data, assumptions will be made for the amount of water lost during garment wet processing. The amount of water evaporated as steam per load will be assumed as 30% of the water used for the generation of steam. The remaining 70% is assumed to be disposed of as wastewater. The total amount of water that evaporates per load will be the amount that evaporates as steam plus the amount of water that evaporates after being absorbed on the pumice stones (see Section 4.3.5).

4.3.5 Water absorbed by stones

A study by Levelton *et al*.(1992) found the liquid absorption capacity of pumice stones used during stone washing operations to be 21,2 % (MEM, 2005). The water absorbed by the stones can evaporate during storage, with some water still present when the stones are re-used. For this dissertation it is assumed that 50% of the absorbed water is evaporated, implying that 10,6 l water is lost through absorption on the stones and subsequent evaporation, per 100 kg of pumice stones used.

4.3.6 Drinking water and ablution facilities

CGM1 has approximately 2 500 employees, who work on two shifts (day shift and night shift) for the factory to run at 24 hours per day (MLE, 2005). Each shift comprises of 1 250 employees. Water used for drinking and personal hygiene ranges between 2 – 5 litres per person per day (DWAF, 1998). For the purpose of this dissertation, a value of 4 l per day per employee will be used, resulting in 10 000 l total water use for drinking and personal hygiene purposes.

Employees at CGM1 make use of ablution facilities, on average, three times per shift (Potlaki, 2004). With the cisterns in the toilets having a capacity of 10 l, a value of 30 l of water for ablution facilities per employee per day will be used in this dissertation; resulting in a total of 75 000 l per day.

4.4 WATER USE FOR THE STONE WASHING/WASHING PROCESS COMBINATION (PROCESS A)

This is the basic process combination within the factory. A water balance for this process is illustrated in Figure 4.3, with the relevant streams (A1 – A11) presented in Table 4.3, as determined in Sections 4.4.1 to 4.4.11.

4.4.1 Desizing water [Stream A1]

The amount of water used in the desizing operation for this process combination is 500 l per load (Table 3.1), with the number of loads processed during the 24-day period of data collection equal to 56 loads (Table 4.1). This implies that 1 167 l/day was used for desizing water during this process combination.

4.4.2 Rinsing water [Stream A2]

The amount of water used in the rinsing operation for the stone washing/washing process combination is shown in Table 3.1. The rinsing operation in this process combination is undertaken three times; after the desizing operation, the stone washing operation and the washing operation; resulting in a total water use of 4 000 l per load. With 56 loads for the rinsing operation carried out during 24 days of data collection, a total of 9 333 l/day rinsing water is used during Process A.

4.4.3 Stone washing water [Stream A3]

From Table 3.1 the amount of water used per stone washing operation is 500 l. For 56 loads over 24 days 1 167 l/day is used as stone washing water.

4.4.4 Washing water [Stream A4]

The amount of water used in the washing operation for this process combination is 500 l (Table 3.1). With 56 loads for the washing operation carried out during 24 days of data collection, a total of 1 167 l/day washing water is used during Process A.

4.4.5 Softening water [Stream A5]

From Table 3.1 the amount of water used in the softening operation for this process combination is 500 l. For 56 loads processed over the 24-day period of data collection, 1 167 l/day of water is used as softening water.

4.4.6 Checking water [Stream A6]

The checking operation is carried out once in the stone washing/washing process combination, which is after the stone washing operation (Section 3.4.6). The amount of water used for checking is approximated as 50 l per checking operation (Section 4.3.1). This implies that 56 checking operations were done for this process combination during 24 days period of data collection, resulting in a total of 117 l/day of water used for the checking operation.

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4.4.7 Water in chemicals [Stream A7]

The quantities of chemicals used in the various operations of the stone washing/washing process combination are shown in Table 3.1. The total amount of chemicals used for each load processed is 3 l. This implies that 168 l of chemicals were used for 56 loads processed during the 24-day period of data collection, resulting in 7 l/day of water in chemicals.

4.4.8 Water used for steam [Stream A8]

Section 4.3.2 outlines an average of 29,2 l of water to be used per steam operation and Table 4.2 outlines the total number of operations that used steam in the stone washing/washing process combination during the period of data collection to be 112. This implies a total of 3 270 l of water used for steam production for this process combination during the 24 days of data collection, resulting in 136 l/day of water used for steam.

4.4.9 Cleaning water [Stream A9]

As outlined in Section 4.3.1, water used for cleaning floors in the washroom is not measured or controlled. From Section 4.8 the municipal water supplied by WASA is 937 500 l/day and the water returned from the wastewater treatment plant to the factory is 300 000 l/day. The total amount of water used in the production processes is thus 1 152 500 l/day (937 500 + 300 000 – 10 000 – 75 000), see Section 4.8. Now, the total amount of water used for the four processes is as follows:

Process A = 14 261 l/day (∑A1 – A8) + cleaning water A9 (Section 4.4);
Process B = 12 158 l/day (∑B1 – B10) + cleaning water B11 (Section 4.5);
Process C = 523 856 l/day (∑C1 – C8) + cleaning water C9 (Section 4.6); and
Process D = 245 667 l/day (∑D1 – D10) + cleaning water D11 (Section 4.7).

From the above the total amount of water used in the four process combinations, excluding cleaning water, is 795 942 l/day. The total amount of water thus used for cleaning is 356 558 l/day.

The amount of water used by each process, as a percentage of the total water used, is as follows:
Process A = 1,79% (14 261/795 942 x 100)
Process B = 1,53% (12 158/795 942 x 100)
Process A = 65,82% (523 856/795 942 x 100)
Process A = 30,86% (245 667/795 942 x 100)

In order to determine reasonable values for cleaning water in the respective processes, an assumption is made that cleaning water used during a particular process would be proportional to the amount of water used for that process. Thus cleaning water used for Process A is 6 382 l/day (1,79% of 356 558) and total water used for Process A is 20 643 l/day (∑A1 – A9).

4.4.10 Evaporation [Stream A10]

Evaporation consists of water lost as steam (Section 4.3.4) and water evaporated from stored pumice stones (Section 4.3.5). The water evaporated as steam will thus be 30% of stream A8, namely 41 l/day.

For this process combination, 3 drums of stones were used and each drum weighed 50 kg. This implies, from the assumption in Section 4.3.5, that 16 l (10,6 x 150/100) water is evaporated after absorption on the stones per load. With 56 loads over the 24-day period, this resulted in 37 l/day. Thus total evaporation is 78 l/day.

4.4.11 Wastewater [Stream A11]

The amount of water discharged as wastewater for this process combination is the difference between all the input water (Streams A1 to A9) and total evaporation (Stream A10), resulting in 20 565 l/day discharged as Stream A11.

Table 4.3 Flow rates for the operations in the stone washing/washing process combination.

Stream	Flow rate (l/d)	Source
A1	1 167	Section 4.4.1
A2	9 333	Section 4.4.2
A3	1 167	Section 4.4.3
A4	1 167	Section 4.4.4
A5	1 167	Section 4.4.5
A6	117	Section 4.4.6
A7	7	Section 4.4.7
A8	136	Section 4.4.8
A9	6 382	Section 4.4.9
A10	78	Section 4.4.10
A11	20 565	A1 + A2 + A3 + A4 + A5 + A6 +A7 + A 8 + A9 – A10

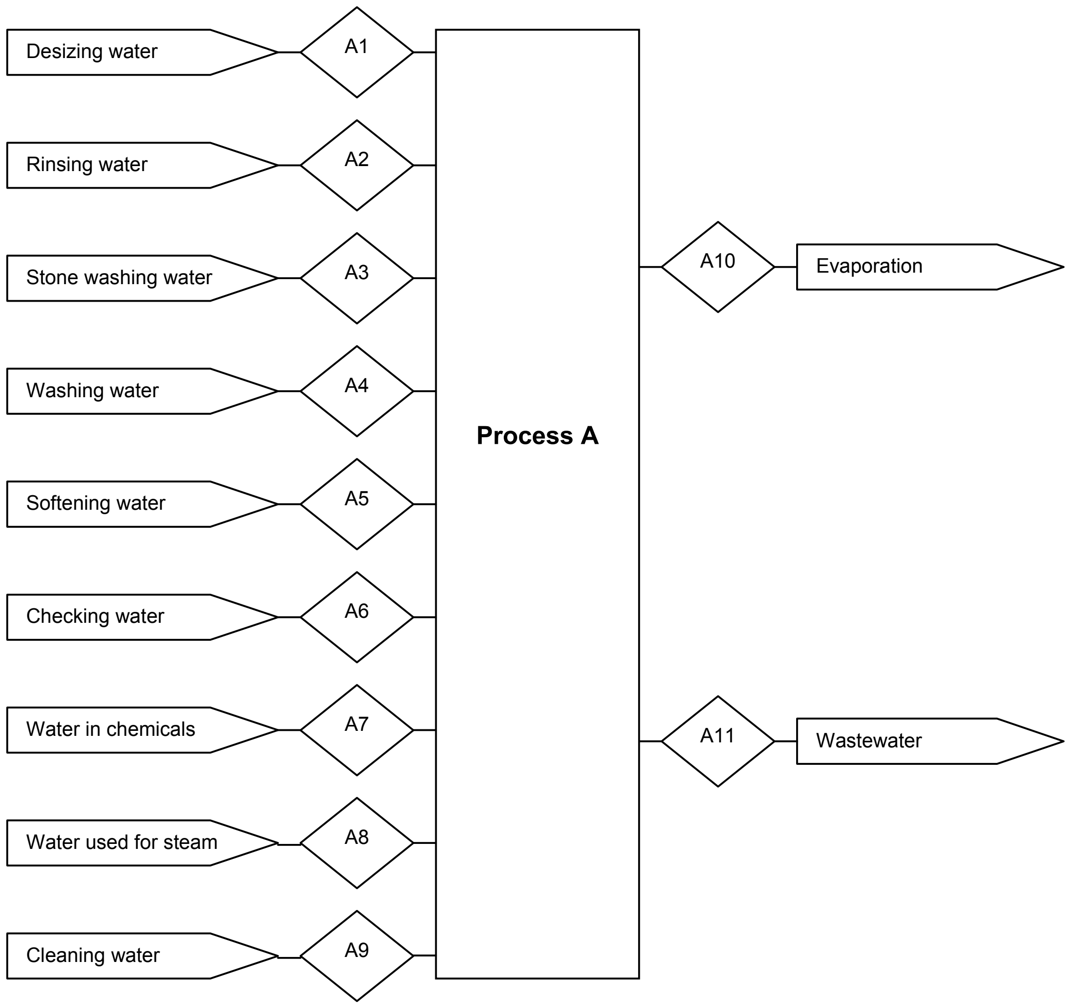

Figure 4.3 Water balance for the stone washing/washing process combination.

4.5 WATER USE FOR THE STONE WASHING/BLEACHING PROCESS COMBINATION (PROCESS B)

A water balance for this process is illustrated in Figure 4.4, with the relevant streams (B1 – B13) presented in Table 4.4, as determined in Sections 4.5.1 to 4.5.13.

4.5.1 Desizing water [Stream B1]

The amount of water used in the desizing operation for this process combination is 500 l per load (Table 3.2), with the number of loads processed during the 24-day period of data collection equal to 30 loads (Table 4.1). This implies that 625 l/day was used for desizing water during this process combination.

4.5.2 Rinsing water [Stream B2]

The amount of water used in the rinsing operation for the stone washing/bleaching process combination is shown Table 3.2. The rinsing operation in this process combination is undertaken three times; after the desizing operation, the stone washing operation and the continuous bleaching operation, resulting in a total water use of 4 500 l per load. With 30 loads for the rinsing operation carried out during 24 days of data collection, a total of 5 625 l/day rinsing water is used during Process B.

4.5.3 Stone washing water [Stream B3]

From Table 3.2 the amount of water used per stone washing operation is 500 l. For 30 loads over 24 days, 625 l/day is used as stone washing water.

4.5.4 Bleaching water [Stream B4]

The amount of water used in the bleaching operation for this process combination is 1 500 l (Table 3.2). With 30 loads for the bleaching operation carried out during 24 days of data collection, a total of 1 875 l/day bleaching water is used during Process B.

4.5.5 Neutralisation water [Stream B5]

The amount of water used in the neutralisation operation for this process combination is 1 500 l (Table 3.2). For 30 loads processed over 24 days, 1 875 l/day is used as neutralisation water.

4.5.6 Continuous bleaching water [Stream B6]

The amount of water used in the continuous bleaching operation for this process combination is 500 l per load (Table 3.2). With 30 loads processed during the 24-day period of data collection, 625 l/day is used for continuous bleaching water during this process combination.

4.5.7 Softening water [Stream B7]

The amount of water used in the softening operation is 500 l as shown in Table 3.2. For 30 loads processed over the 24-day period of data collection, 625 l/day of water is used as softening water.

4.5.8 Checking water [Stream B8]

As outlined in Section 3.4.6, the checking operation is carried out twice in the stone washing/bleaching process combination, which is after the stone washing and neutralisation operations. The amount of water used for checking is approximated as 50 l per checking operation (Section 4.3.1). This implies that 60 checking operations were undertaken for this process combination during the 24-day period of data collection, resulting in a total of 125 l/day of checking water.

4.5.9 Water in chemicals [Stream B9]

The quantities of chemicals used in the various operations of the stone washing/bleaching process combination are shown in Table 3.2. The total amount of chemicals used for each load processed is 9,5 l. Thus 30 loads processed during the period of data collection result in 12 l/day of water in chemicals.

4.5.10 Water used for steam [Stream B10]

Section 4.3.2 outlines an average of 29,2 l of water to be used per steam operation and Table 4.2 outlines the total number of operations that used steam in the stone washing/bleaching process combination during the period of data collection to be 120; resulting in 146 l/day of water used for steam.

4.5.11 Cleaning water [Stream B11]

Similarly to Section 4.4.9: cleaning water used for Process B will be 5 455 l/day (1,53% of 356 558) and total water used for Process B is 17 613 l/day (∑B1 – B11).

4.5.12 Evaporation [Stream B12]

Similarly to Section 4.4.10: water evaporated as steam will be 30% of Stream B10, resulting in 44 l/day; and with two drums of pumice stones used per load (Table 3.2), an amount of 13 l/day (10,6 x 30/24) will be lost due to evaporation of water from stones; resulting in 57 l/day total evaporation.

4.5.13 Wastewater [Stream B13]

The amount of water discharged as wastewater for this process combination is the difference between all the input water (Streams B1 to B11) and total evaporation (Stream B12), resulting in 17 556 l/day being discharged as Stream B13.

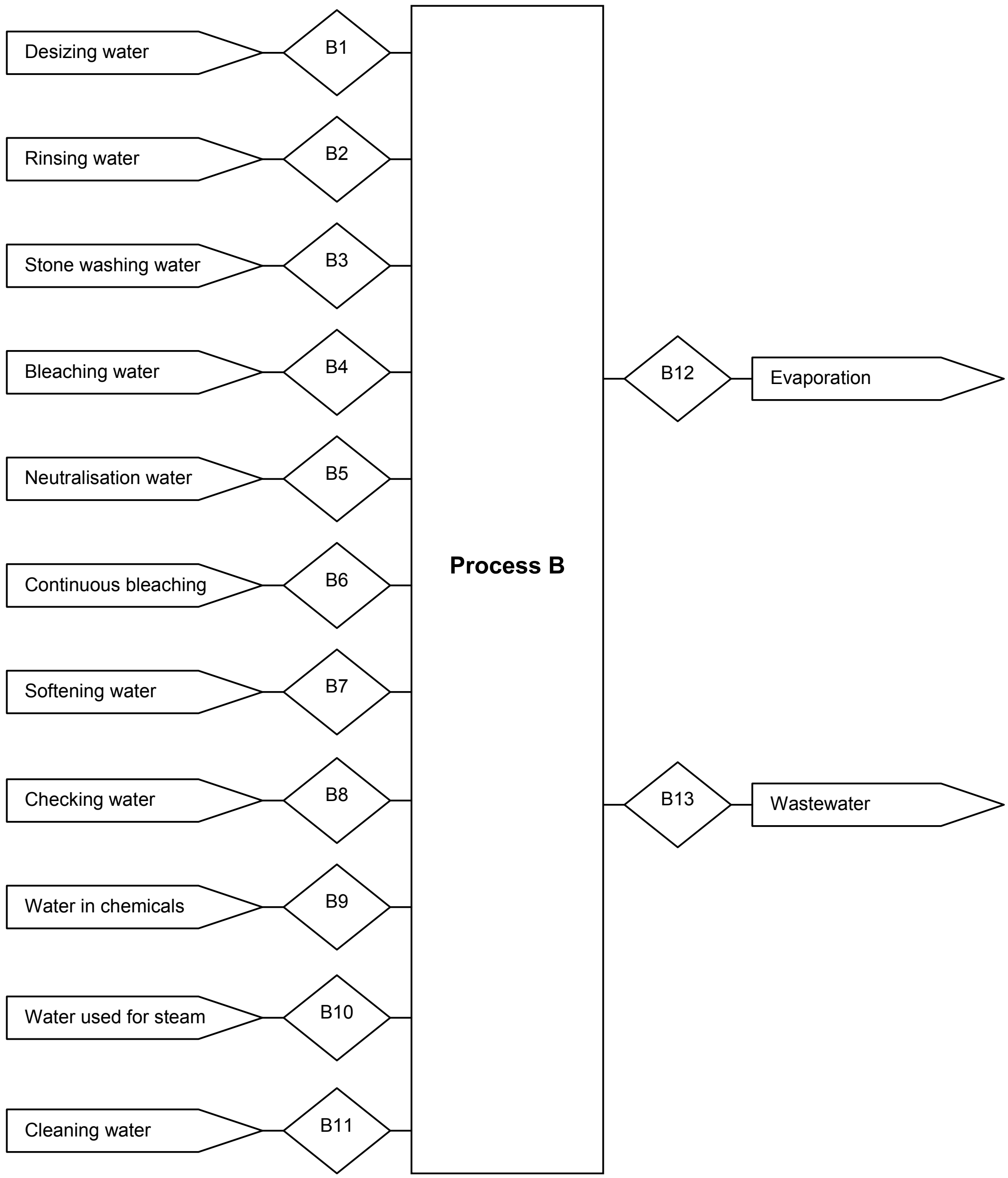

Figure 4.4 Water balance for the stone washing/bleaching process combination.

Table 4.4 Flow rates for the operations in the stone washing/bleaching process combination.

Stream	Flow rate (l/d)	Source
B1	625	Section 4.5.1
B2	5 625	Section 4.5.2
B3	625	Section 4.5.3
B4	1 875	Section 4.5.4
B5	1 875	Section 4.5.5
B6	625	Section 4.5.6
B7	625	Section 4.5.7
B8	125	Section 4.5.8
B9	12	Section 4.5.9
B10	146	Section 4.5.10
B11	5 455	Section 4.5.11
B12	57	Section 4.5.12
B13	17 556	B1 + B2 + B3 + B4 + B5 + B6 + B7 + B8 + B9 + B10 + B11 – B12

4.6 WATER USE FOR THE STONE WASHING/DYEING PROCESS COMBINATION (PROCESS C)

A water balance for this process is illustrated in Figure 4.5, with the relevant streams (C1 – C11) presented in Table 4.5, as determined in Sections 4.6.1 to 4.6.11.

4.6.1 Desizing water [Stream C1]

The amount of water used in the desizing operation for this process combination is 500 l per load (Table 3.4), with the number of loads processed during the 24-day period of data collection equal to 1 635 loads (Table 4.1). This implies that 34 063 l/day is used for desizing water during this process combination.

4.6.2 Rinsing water [Stream C2]

The amount of water used in the rinsing operation for this process combination is shown Table 3.4. The rinsing operation in this process combination is undertaken three times; after the desizing operation and twice after the stone washing operation (with stones and without stones), resulting in a total of 4 500 l per load. With 1 635 loads for the rinsing operation undertaken during 24 days of data collection, a total of 306 563 l/day rinsing water is used in Process C.

4.6.3 Stone washing water [Stream C3]

From Table 3.4 the amount of water used per stone washing operation is 500 l. For 1 635 loads processed over 24 days, 34 063 l/day is used as stone washing water.

4.6.4 Dyeing water [Stream C4]

The types and quantities of chemicals used, as well as the amount of water used (1 000 l), at CGM1 for the dyeing operation during the 24 days of data collection are outlined in Table 3.4. A total of 1 635 dyeing operations were carried out in the 24 days of data collection, resulting in 68 125 l/day of water used as dyeing water.

4.6.5 Softening water [Stream C5]

The amount of water used in the softening operation for this process combination is 1 000 l per load (Table 3.4). With 1 635 loads processed during the 24-day period of data collection, 68 125 l/day is used for softening water during this process combination.

4.6.6 Checking water [Stream C6]

As outlined in Section 3.4.6, the checking operation is carried out twice in this process combination, which is after the stone washing operation and the dyeing operation. The amount of water used for checking is approximated as 50 l per checking operation (Section 4.3.1). This implies that 3 270 checking operations were undertaken for the stone washing/dyeing process combination during the 24-day period of data collection, resulting in a total use of 6 813 l/day of checking water.

4.6.7 Water in chemicals [Stream C7]

The quantities of chemicals used in the various operations of the stone washing/dyeing process combination are shown in Table 3.4. The total amount of chemicals used for each load processed is 2 l. Thus 1 635 loads processed during the period of data collection result in 136 l/day of water in chemicals.

4.6.8 Water used for steam [Stream C8]

Section 4.3.2 outlines an average of 29,2 l of water to be used per steam operation and Table 4.2 outlines the total number of operations that used steam in this process combination during the 24-day period of data collection to be 4 905; resulting in 5 968 l/day of water used for the generation of steam.

4.6.9 Cleaning water [Stream C9]

Similarly to Section 4.4.9: cleaning water used for Process C will be 234 687 l/day (65,82% of 356 558) and total water used for Process C is 758 543 l/day (∑C1 – C9).

4.6.10 Evaporation [Stream C10]

Similarly to Section 4.4.10: water evaporated as steam will be 30% of Stream C8, resulting in 1 790 l/day; and with two drums of pumice stones used per load (Table 3.4), an amount of 722 l/day (10,6 x 1 635/24) will be lost due to evaporation of water from stones; resulting in 2 512 l/day total evaporation.

4.6.11 Wastewater [Stream C11]

The amount of water discharged as wastewater for this process combination is the difference between all the input water (Streams C1 to C9) and total evaporation (Stream C10), resulting in 756 031 l/day discharged as Stream C11.

Table 4.5 Flow rates for the operations in the stone washing/dyeing process combination.

Stream	Flow rate (l/d)	Source
C1	34 063	Section 4.6.1
C2	306 563	Section 4.6.2
C3	34 063	Section 4.6.3
C4	68 125	Section 4.6.4
C5	68 125	Section 4.6.5
C6	6 813	Section 4.6.6
C7	136	Section 4.6.7
C8	5 968	Section 4.6.8
C9	234 687	Section 4.6.9
C10	2 512	Section 4.6.10
C11	756 031	C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 - C10

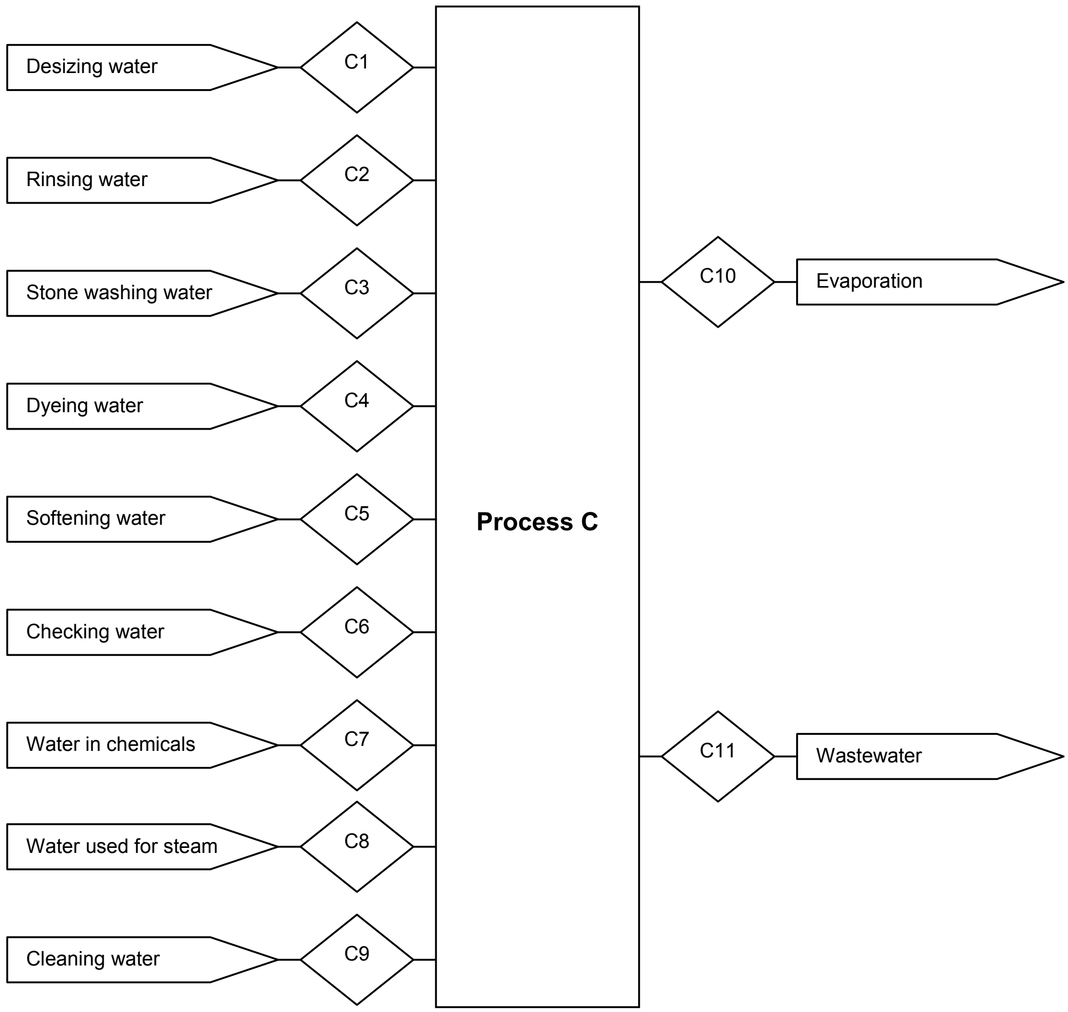

Figure 4.5 Water balance for the stone washing/dyeing process combination.

4.7 WATER USE FOR THE STONE WASHING/BLEACHING/DYEING PROCESS COMBINATION (PROCESS D)

A water balance for this process is illustrated in Figure 4.6, with the relevant streams (D1 – D13) presented in Table 4.6, as determined in Sections 4.7.1 to 4.7.13.

4.7.1 Desizing water [Stream D1]

The amount of water used in the desizing operation for this process combination is 500 l per load (Table 3.5), with the number of loads processed during the 24-day period of data collection equal to 574 loads (Table 4.1). This implies that 11 958 l/day is used for desizing water during this process combination.

4.7.2 Rinsing water [Stream D2]

The amount of water used in the rinsing operation for the stone washing/bleaching/dyeing process combination is shown Table 3.5. The rinsing operation in this process combination is undertaken three times; that is after the desizing operation, the stone washing operation and the neutralisation operation resulting in a total of 4 500 l per load. With 574 loads for the rinsing operation undertaken during 24 days of data collection, a total of 107 625 l/day rinsing water is used in Process D.

4.7.3 Stone washing water [Stream D3]

From Table 3.5 the amount of water used per stone washing operation is 500 l. For 574 loads processed over 24 days, 11 958 l/day is used as stone washing water.

4.7.4 Bleaching water [Stream D4]

The amount of water used in the bleaching operation for this process combination is 1 500 l (Table 3.5). With 574 loads for the bleaching operation carried out during 24 days of data collection, a total of 35 875 l/day bleaching water is used during Process D.

4.7.5 Neutralisation water [Stream D5]

The amount of water used in the neutralisation operation for this process combination is 1 500 l (Table 3.5). For 574 loads processed over 24 days, 35 875 l/day is used as neutralisation water.

4.7.6 Dyeing water [Stream D6]

The amount of water used per dyeing operation for Process D is 500 l (Table 3.5). A total of 574 dyeing operations were carried out in the 24 days of data collection, resulting in 11 958 l/day of water used as dyeing water.

4.7.7 Softening water [Stream D7]

The amount of water used in the softening operation is 1 000 l per load (Table 3.5). With 574 loads for the softening operation carried out during the 24-day period of data collection, a total of 23 917 l/day dyeing water is used during Process D.

4.7.8 Checking water [Stream D8]

The checking operation is carried out three times in this process combination, which is after the stone washing, neutralisation and dyeing operations (Section 3.4.6). For 574 loads undergoing three checking operations each, 1 722 checking operations were undertaken during the 24-day period of data collection. The amount of water used for checking is approximated as 50 l per checking operation (Section 4.3.1), resulting in 3 588 l/day of checking water.

4.7.9 Water in chemicals [Stream D9]

The quantities of chemicals used in the various operations of the stone washing/bleaching/dyeing process combination are shown in Table 3.5. The total amount of chemicals used for each load processed is 5 l. Thus 574 loads processed during the 24-day period of data collection result in 120 l/day of water in chemicals.

4.7.10 Water used for steam [Stream D10]

Section 4.3.2 outlines an average of 29,2 l of water to be used per steam operation and Table 4.2 outlines the total number of operations that used steam in this process combination during the 24-day period of data collection to be 2 296; resulting in 2 793 l/day of water used for steam.

4.7.11 Cleaning water [Stream D11]

Similarly to Section 4.4.9: cleaning water used for Process D will be 110 034 l/day (30,86% of 356 558) and total water used for Process D is 355 701 l/day (∑D1 – D11).

4.7.12 Evaporation [Stream D12]

Similarly to Section 4.4.10: water evaporated as steam will be 30% of Stream D10, resulting in 838 l/day; and with one drum of pumice stones used per load (Table 3.5), an amount of 127 l/day (10,6 x 50/100 x 574/24) will be lost due to evaporation of water from stones; resulting in 965 l/day total evaporation.

4.7.13 Wastewater [Stream D13]

The amount of water discharged as wastewater for this process combination is the difference between all the input water (Streams D1 to D11) and total evaporation (Stream D12), resulting in 354 736 l/day discharged as Stream D13.

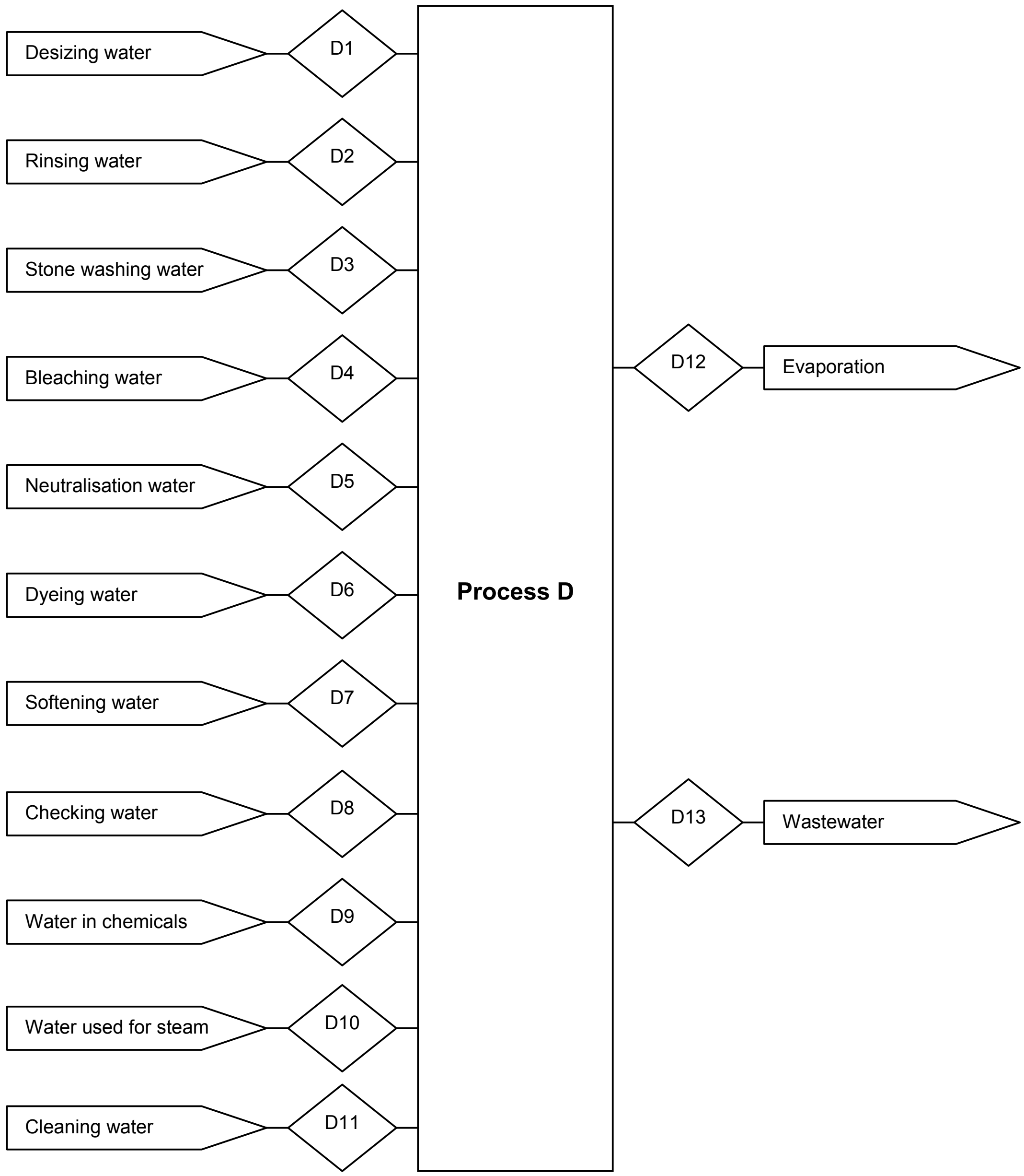

Figure 4.6 Water balance for the stone washing/bleaching/dyeing process combination.

Table 4.6 Flow rates for the operations in the stone washing/bleaching/dyeing process combination.

Stream	Flow rate (l/d)	Source
D1	11 958	Section 4.7.1
D2	107 625	Section 4.7.2
D3	11 958	Section 4.7.3
D4	35 875	Section 4.7.4
D5	35 875	Section 4.7.5
D6	11 958	Section 4.7.6
D7	23 917	Section 4.7.7
D8	3 588	Section 4.7.8
D9	120	Section 4.7.9
D10	2 793	Section 4.7.10
D11	110 034	Section 4.7.11
D12	965	Section 4.7.12
D13	354 736	D1 + D2 + D3 + D4 + D5 + D6 + D7 + D8 + D9 + D10 + D11 – D12

4.8 OVERALL WATER BALANCE FOR THE CGM 1 FACTORY

Stream	Flow rate (l/d)	Source
Municipal water (E)	937 500	WASA (2005)
Stone washing/washing process combination (A)	20 643	Section 4.4.9
Stone washing/bleaching process combination (B)	17 613	Section 4.5.11
Stone washing/dyeing process combination (C)	758 543	Section 4.6.9
Stone washing/bleaching/dyeing process combination (D)	355 701	Section 4.7.11
Drinking water (F)	10 000	Section 4.3.6
Ablution facilities (G)	75 000	Section 4.3.6
Recycled water (back to factory) (H)	300 000	Molaoli (2005)
Wastewater treatment plant (I)	1 148 888	A11 + B13 + C11 + D13
Evaporation (J)	3 612	A10 + B12 + C10 + D12
Discharge to river (L)	848 888	I - H
Municipal treatment works (K)	85 000	F + G

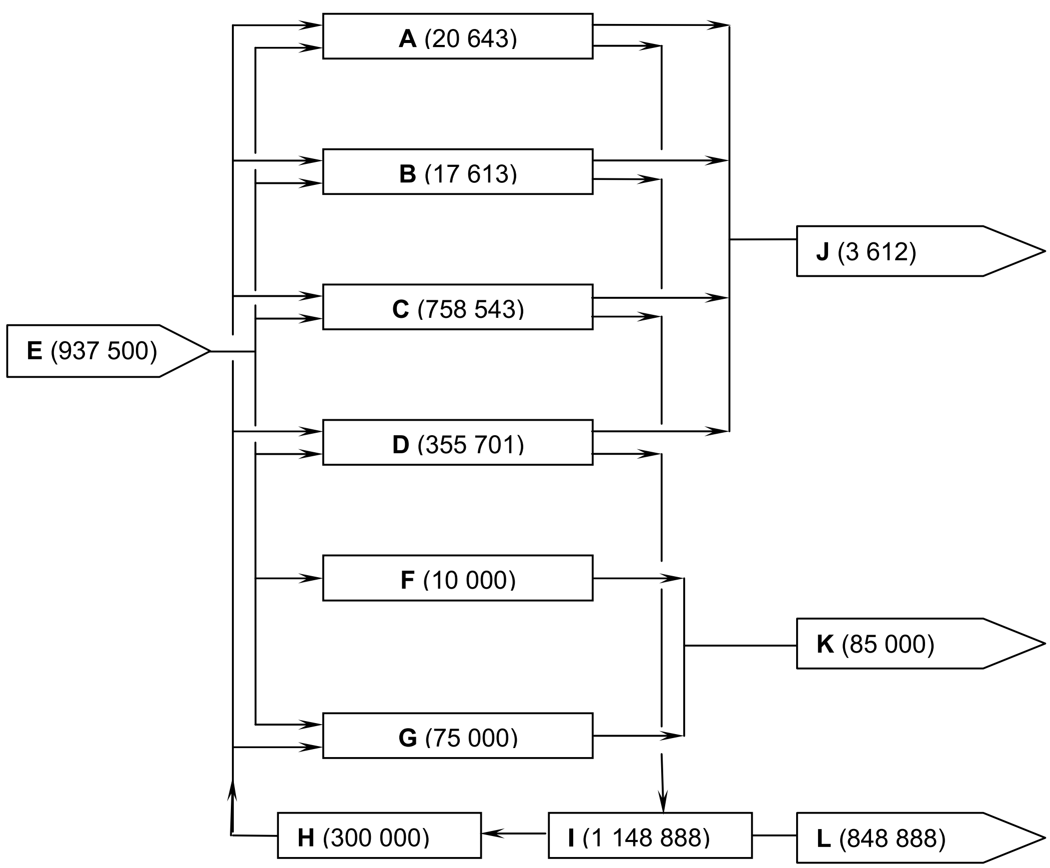

Figure 4.7 Simplified water balance for processes entailed at CGM1.

CHAPTER 5

Conclusions and Recommendations

In every industrial sector where there is production of waste; be it solid, liquid or gaseous; the first tier of management is waste minimisation and pollution prevention to reduce the quantities and strength of wastes generated. However, not all wastes from industrial activities can be minimised or recycled, which introduces treatment as the second tier of waste management. The final option in the management of waste is disposal. In order to provide comprehensive and proper wastewater management actions for CGM Industrial Pty (Ltd) (CGMI), all three tiers will be addressed.

5.1 WASTE MINIMISATION

In the past, focus on waste has been end-of-pipe treatment technologies, but current trends are towards waste minimisation and pollution prevention, which are implemented in a variety of ways (Watts, 1997).

5.1.1 Reduction of wastewater volume

Most wastewater leaving a textile industry needs treatment before it can be reused in any way. However, there are waste streams that can still be reused without treatment, but this requires segregation of the streams from the different wet processing operations. It was observed during the time spent at the company that the wastewater from CGMI factories is not segregated and this poses a problem in reusing any of the streams without treatment.

Denim wet processing wastewater is very variable in character and studies have shown that the highest total suspended solids (TSS) content is at the first operation of the wet processing; the desizing operation. This is due to the removal of the sizing agent and the chemicals used in the manufacturing of the denim fabric. High levels of TSS are also experienced in the stone washing operation due to the fragmentation of the pumice stones. These types of wastewater require treatment before they can be reused.

On the other hand, the rinsing operations produce wastewaters with lower solids content and it might be of a good practice to segregate the wastewater from the different operations entailed in CGMI's factories in order to reuse the rinsing wastewaters. This will have savings on the company's wastewater productions as well as treatment costs because specific rinsing water can be reused (in another load of the same requirements) as process water for a preceding operation; that is, rinsing water following a desizing operation can be reused as desizing water for the next load. It should, however, be taken into consideration that rinsing water also contain a significant amount of colour, which is likely to stain the white pockets of jeans if used as process water.

It is therefore recommended that the company investigate the acceptable levels of colour that allows rinsing water to be used as process water without staining. The investigation results can also be used in the determination of treatment requirements for different wastewater streams and thus contributing a lot to the company's savings. There may also be waters that can be collected and reused without the necessity for treatment, once the required quality of water for different operations is established.

5.1.2 Good house keeping practices

It was also observed during the time spent at CGM 1 that chemicals are sometimes applied in excessive and unnecessary amounts in the factory. Chemicals that are often overused include detergents and enzymes. Using more chemicals than is necessary results in slippery floors that require cleaning, resulting in increased wastewater production.

In this regard it is recommended that the company engages in the purchase of automatic feed systems that can be programmed based on the weight and style of the load to be processed. Although this might be expensive, it will in the long run save the company money with regard to spillages, wrong chemical mixes (that have to be discarded) and large amounts of water used to clean up floors.

Avoiding spillages (which have to be cleaned off by running water over the floors in order to dilute the chemicals to prevent shock loads from reaching the treatment plant) and preparing the precise quantities of chemical mixes will not only conserve the water, but will reduce the strength of the wastewater. It is very important to adjust chemical loading as well as process water to the weight of the load and the style of the garments to be processed. Failure to do these results, not only in increased amounts of wastewater, but cost to the company's production because such a load will have to be reprocessed.

Cleaning of floors is solely depended on the judgement of the operators and this operation is resulting in significant water losses. It was observed during time spent at the company that there is no consistency in cleaning floors. Lack of consistency in cleaning floors seems to be a major problem that is costing the company a lot of money in water costs as well as treatment costs. It is recommended that efforts are made to only clean the floors when necessary and high pressure valves that automatically close after a certain quantity of water has run through the hose pipe should be installed.

Although a number of recommendations have been given with regard to good house keeping practices, effective house keeping depends on the efforts, cooperation and support of the operating personnel to implement the recommendations to the fullest extent possible in order to reduce the industry's pollutional load (Jones, 1973).

5.1.3 Substitution of chemicals

Substitution of chemicals can result in significant reduction of pollution load and can even make water reclamation possible. Chemicals are sometimes added to counteract the negative effects of other chemicals. Instead of adding more chemicals to the bath, the offending chemicals can be substituted with a chemical with fewer harmful effects. For example, hydrogen peroxide can be used instead of calcium hypochlorite during actual bleaching operations, which would also negate the use of sodium hypothiosulphide to neutralise the reaction of calcium hypochlorite.

Metals are used as essential ingredients in some dyes and sizing agents, ultimately forming part of any wastewater produced. The metals in wastewater can inhibit biological treatment resulting in inefficiently treated wastewater. It is recommended that Material Safety Data Sheets for every chemical reaching the industry is comprehensively assessed and any hazardous chemicals be substituted with environmentally friendly products. The substitution of chemicals can often be done without any significant effect on the quality of the product.

5.1.4 Process modifications

Some operations within the wet processing combinations require the use of hot water. The water is heated by pumping steam generated from a boiler into the washing machines. The washing machines are in the same room as the dryers that are operated at high temperatures. The company should investigate the possibility of passing process water through the dryers before reaching the washing machines. Thus heating the process water to the desired temperatures with subsequent savings in energy and water used for steam generation.

5.1.5 Reduction of process chemicals

It was identified that in the CGM 1 factory, some operations had to be re-run because anticipated results had not been acquired. This might be due to the loss of strength of those chemicals. It is recommended that the company engages in quality control of the chemicals used in wet processing operations. The strength of the chemicals supplied should be tested, because some chemicals lose their strength or efficiency with time. This will improve operations efficiency and reduces the need to re-run operations due to inefficient results. The impact will be on water savings, treatment savings, as well as chemical savings.

5.2 EFFLUENT TREATMENT AND DISPOSAL

The stages for effluent treatment from the five factories comprising CGMI are not efficient for proper treatment of the wastewater from the factories. The wastewater from the plant is reused in the ablution facilities at the factories' site and it has been observed that the treated water is still foamy. This has also been highlighted by nearby residents in a local newspaper. For the poor community, it is seen as a bargain to use the water for laundry because they do not need to buy soap (Lesiamo, 2005). However, this is not acceptable with regard to environmental, health and safety requirements.

The plant does not undertake any sampling or analysis of wastewater prior to discharge. It was, however, identified that some of the wastewater discharged from the industry's wastewater plant is not in compliance with wastewater discharge standards/guidelines through observations made during the time spent at the industry, as outlined in Figure 3.20. Section 45 of the Environment Act, 2001 of Lesotho prohibits the discharge of any hazardous substance into any waters or any other part of the environment except in accordance with the industrial wastewater guidelines and other relevant guidelines prescribed by the Lesotho Environment

Authority. Lesotho has not yet developed any guidelines but has adopted Industrial Wastewater Guidelines for South Africa. Based on the South African Guidelines, wastewater to be discharged into water bodies or the environment should be clear of any colour.

It is therefore recommended that further investigations be undertaken by the company to identify practical efficient treatment methods of the wastewater; to discourage the use of the "soapy" water from the industry's treatment plant by the nearby residents; and to ensure safe disposal into the water resources without detrimental effects to the water inhabitants, as well as users downstream. It has also been highlighted that the treatment plant cannot accommodate the effluent from all the factories, resulting in discharging a portion of untreated water into the nearby stream resulting in pollution problems (Figure 3.20). The company should be aware that Lesotho is a signatory to the SADC Protocol of Shared Watercourses and it is against the principles of this protocol to engage in pollution of water bodies.

The waste collected from the different stages of the treatment plant can be dewatered to significantly reduce the volume of the waste to be disposed off and thus conserving disposal sites.

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