NATSURV 13

WATER AND WASTE-WATER MANAGEMENT IN THE TEXTILE INDUSTRY

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prepared for the

WATER RESEARCH COMMISSION

by

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

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Steffen Robertson and Kirsten
265 Oxford Road
ILLOVO
2196

PO Box 55291
NORTHLANDS
2116
Tel: (011) 441-1111
Fax: (011) 880-8086

Available from:

Water Research Commission
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FOREWORD

The need for guidelines to assist industry in reducing its water intake and managing its waste-water disposal as effectively as possible is of national concern in the RSA in view of the country's water scarcity and the growing deterioration in the quality of available water supplies.

To establish norms for water intake and waste-water disposal, the Water Research Commission (WRC), in collaboration with the Department of Water Affairs (DWA), contracted a firm of consulting engineers, to undertake a National Industrial Water and Waste-water Survey (NATSURV) of all classes of industry. The results obtained in the survey of the textile industry form the basis of this guide on **Water and Waste-water Management in the Textile Industry.**

It is expected that this guide will be of value to the industry itself and to other interested parties such as municipalities, legislators, researchers and consultants in the water and effluent fields.

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Dr O O Hart	Water Research Commission (Chairman)
Mr D F Sutton	Department of Water Affairs and Forestry
Mr A W La Cock	Cape Town City Council
Mr S Gribi	SA Dyers and Finishers Association
Mr P Skivington	Steffen Robertson and Kirsten
Mr G N Steenveld	Steffen Robertson and Kirsten.

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Assistance given by the Textile Federation is gratefully acknowledged, as is the cooperation of the Pollution Research Group at the University of Natal in making available information obtained from their activities in the textile industry in the course of other projects carried out on behalf of the Water Research Commission.

SUMMARY

The textile industry in the RSA ("the Industry") comprises a group of related industrial operations which use various natural and synthetic fibres as the raw materials to produce a wide variety of end-products, ranging from processed fibres to woven materials to finished garments or piece goods. This guide is addressed primarily at the sector of the industry which uses water extensively in its processing operations.

Most of the field data collected is from the Western Cape area, although major textile plants in the Eastern Cape and Natal have also been surveyed. The data obtained has been correlated with other data available on water intake and effluent generation in the Industry, as referenced in the text.

Overall, water intake by the Industry is estimated to be around 30 x 10^6 m^3/a, of which 70 to 80% is returned as industrial effluent.

Specific water intake (SWI) was found to vary from 95 to 400 ℓ/kg of material processed. The wide range in SWI values observed is partly due to the diverse nature of the Industry, for example in terms of the types and proportions of different fibres processed, but also reflects a relative lack of water efficiency at some factories compared to others with similar processing operations. The latter factor indicates that significant reductions in water intake and improvements in water management can be achieved within the Industry.

Specific pollution load (SPL) values were found to vary considerably depending on the type of processing involved, which in turn is affected by the material handled and the type of equipment employed. In general, the waste waters from the Industry have high salinity and range widely in terms of pH values, and, in some cases, have high heavy metal concentrations, colour and (relatively non-biodegradable) organic content.

The strategic approach consequently recommended for reducing overall SWI and SPL values in the Industry is for individual factories to implement water-saving and pollution-reducing measures, using their individual SWI and SPL values as targets against which to measure improvement. Generally applicable measures for reducing water use (i.e. improving water efficiency), for reducing pollutant loads at source, and for providing on-site pretreatment of the effluents arising, are identified in the Guide. These measures should be implemented selectively on a site-specific basis to further the strategic approach indicated above.

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In the schematic diagrams, process operation steps are shown as a single-line box thus ☐ while raw materials, semi-processed materials and products are shown by bold print in a double-line box thus ☐

GLOSSARY

BLEACHING	The chemical (oxidizing or reducing) treatment of textile materials to destroy colouring matter and other impurities.
CARDING	An operation in which raw fibres are aligned.
CARBONIZING	The acid washing of wool to remove residual vegetable matter.
COMBING	An operation in which raw fibres are cleaned by a combing process.
DESIZING	The removal of sizing agents before further finishing of the fabric.
FINISHING	The final operations carried out on yarn or fabric to impart the desired properties and appearance.
FULLING	The alkaline/detergent treatment of wool, followed by roller-milling, to increase body and density.
GREIGE	Woven cloth which has not received any further processing.
KNITTING	The production of fabric by looping together yarn or thread.
MERCERIZING	The treatment of cotton fabric with concentrated sodium hydroxide to impart sheen and improve the wettability of the fabric.
PIECE GOODS	Fabric produced from yarn by weaving or knitting.

SCOURING	The treatment of cotton fabric with hot concentrated sodium hydroxide to remove waxes and pectins from the fabric.
SIZING	The application of a polymeric coating to warp yarn to improve its weaving characteristics; the traditional sizing agent is starch, but more recently synthetic polymers and polymer blends have also been used.
SPECIFIC EFFLUENT VOLUME	The effluent volume for a particular period divided by the product quantity processed in the same period.
SPECIFIC POLLUTION LOAD	The mass of given pollutant for a particular period divided by the product quantity processed in the same period.
SPECIFIC WATER INTAKE	The water intake for a particular period divided by the product quantity processed in the same period.
SPINNING	The production of yarn from fibres or filaments.
SUINT	Saline excretions from the skin of sheep, accumulating in raw wool as an impurity which is removed by washing (scouring).
WARP	The longitudinal threads in a length of fabric.
WEAVING	The production of fabric by the interlacing of warp and weft yarn threads on a loom.
WEFT	The cross-threads inserted into the warp during weaving.
YARN	Spun fibre.

ABBREVIATIONS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
FOG	Fats, oils and greases
OA	Oxygen absorbed
SEV	Specific effluent volume
SPL	Specific pollution load
SS	Suspended solids
SWI	Specific water intake
SWU	Specific water use
TDIS	Total dissolved inorganic solids
TDS	Total dissolved solids
WRC	Water Research Commission

1 INTRODUCTION

The textile industry in the RSA ("the Industry") comprises a group of related industries engaged in processing activities ranging from yarn and fabric production and finishing through to the manufacture of clothing and other soft goods items[1]. The factories concerned are often referred to as mills (in the text following, the terms "factory" and "mill" are used interchangeably, depending on the context).

The total water intake by the Industry has been assessed at around 30 x 10^6 m^3/a[2]. Definitive categorization of the Industry according to water intake or water use is complicated by a number of factors. One factor is the degree of vertical integration: many major mills are fully integrated vertically i.e. they take in one or more types of the raw fibre and carry out all operations from yarn spinning through fabric production, preparation, dyeing, printing and finishing. Other factories take in varying proportions of undyed and pre-dyed yarn and process accordingly to produce piece goods, or take in varying proportions of yarn (dyed or undyed) and fabric to produce garments.

In terms of water intake per unit of production for processing purposes, extremes in the Industry are represented on the one hand by those factories which employ large numbers of people but carry out essentially "dry" operations such as garment manufacturing, and on the other hand by those factories operating as commission dyers and finishers and using large volumes of water directly for such "wet" processing purposes.

A second major variable affecting the classification of the Industry is the type of fibre processed. Fibre consumption in the industry[9] over the period 1989 to 1991 is indicated in Table 1.1. Depending *inter alia* on market requirements these are also blended in various proportions. Some factories produce only specific blends, while others at various times process any and all of the fibre types and blends. This significantly affects both the water intake and the waste-water characteristics, as the different fibre types have different processing requirements. From Table 1.1 it may be noted that the total fibre consumption by the Industry in the RSA increased moderately from 1987 to 1989 and then declined in 1990 (with a further decline reported [11] in 1991). The proportions of the major fibre types however remained relatively constant over the period 1987 to 1990.

Other variables affecting water intake and effluent characteristics in the Industry are the type of dyestuff used, the method of dyeing and the type of equipment employed. Wide variations in water use and effluent quality for similar products are thus observed. Seasonal variations due to market and fashion demands also affect the situation with regard to water intake and effluent quality.

TABLE 1.1 FIBRE CONSUMPTION IN THE INDUSTRY (1989 TO 1990)

CLASS	FIBRE TYPE	CONSUMPTION (t/a)				% OF TOTAL			
		1987	1988	1989	1990	1987	1988	1989	1990
NATURAL	Cotton	81 300	78 600	84 600	81 200	29,1	27,6	27,8	29,0
	Wool	5 100	6 200	6 700	6 500	1,8	2,2	2,2	2,3
	Mohair	220	250	250	250	<0,1	<0,1	<0,1	<0,1
	Jute, sisal	18 500	16 000	17 000	16 800	6,6	5,6	5,6	6,0
SUB-TOTALS NATURAL		105 120	101 050	108 550	104 750	37,6	35,5	35,7	37,4
SYNTHETIC	Polyester staple	32 000	36 300	39 500	39 000	11,4	12,7	13,0	13,9
	Polyester filament	26 200	28 600	30 100	25 200	10,2	10,0	9,9	9,0
	Nylon	22 900	22 100	22 600	19 600	7,9	7,8	7,4	7,0
	Acrylic	33 800	35 700	39 200	36 400	12,8	12,5	12,9	13,0
	Viscose	14 000	10 700	9 600	11 200	3,8	3,8	3,2	4,0
	Polypropylene, HDPE	36 500	37 800	41 400	39 200	13,5	13,3	13,6	14,1
	Unclassified	8 900	12 600	13 200	4 500	4,5	4,4	4,3	1,6
SUB-TOTALS SYNTHETIC		174 300	183 800	195 600	175 100	62,4	64,5	64,3	62,6
TOTALS		279 420	284 850	304 150	279 850	100,00	100,00	100,00	100,00

To sum up, textile processing operations differ widely from one another both vertically and horizontally. Further differences in water and effluent parameters are introduced due to fashion and seasonal market forces, which affect the type of fibre, processing and finishing used. Specific parameters such as specific water intake (SWI), specific effluent volume (SEV) and specific pollution load (SPL) thus each have relatively wide ranges, as outlined in Section 3.

Approximately 30 x 10^6 m^3/a of water is taken in by the Industry, and around 70 to 80% of the water intake is discharged as industrial effluents. The industrial waste waters generated are characteristically high in dissolved solids, heavy metals and colour, and contain relatively poorly degradable organic components.

The information used in this Guide has been collected from on-site surveys of twelve major textile factories, mainly in the Western Cape but also in the Eastern Cape (one factory) and Natal (one factory). Data on four other plants was obtained by post and telephone. Supplementary information on water use and effluent generation in the Industry has also been collated from published data on other Water Research Commission projects [2,3,4].

2 PROCESS RESUMÉ

2.1 Categorization of the industry

Processing in the Industry is carried out by a group of related industries using a variety of natural and/or synthetic fibres as stock; blending and spinning of various types of fibre as required to produce specific yarn mixes; weaving and knitting processes to produce fabric; bleaching, dyeing, printing and finishing of the fabric; and manufacture of soft piece goods from fabric. The fibre concerned may be dyed and finished in one or more forms as stock, yarn, fabric or garments. In this guide, the focus is on the "wet" operations and sectors in the Industry.

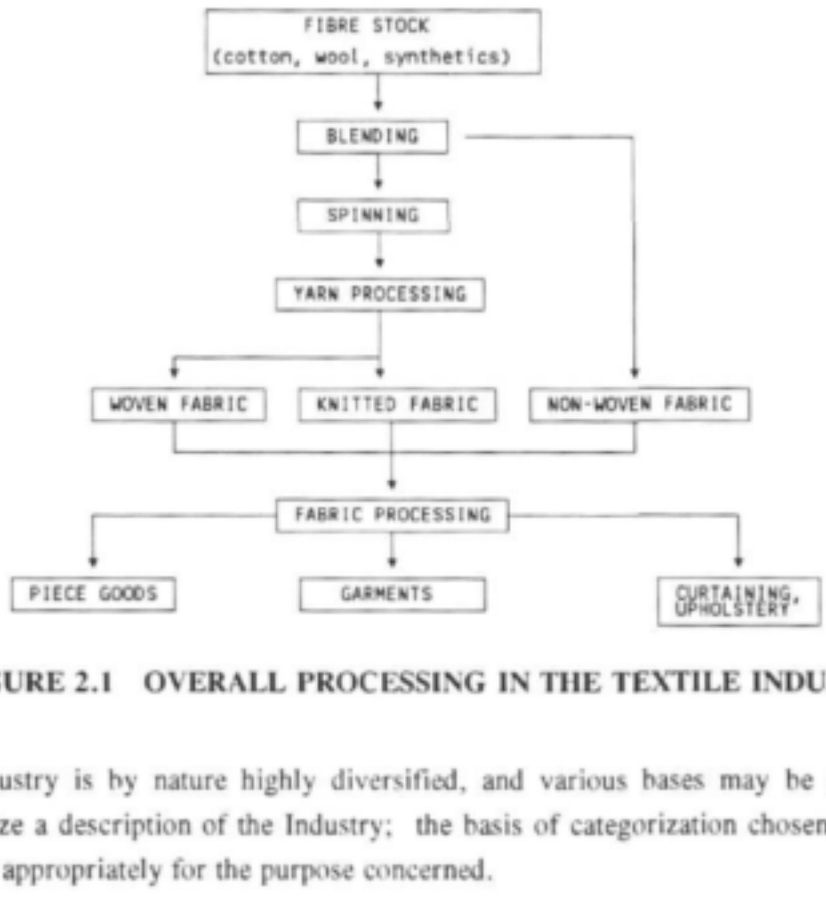

FIGURE 2.1 OVERALL PROCESSING IN THE TEXTILE INDUSTRY

The Industry is by nature highly diversified, and various bases may be adopted to rationalize a description of the Industry; the basis of categorization chosen should be selected appropriately for the purpose concerned.

In the context of this guide, three methods of classification are considered, firstly in terms of the unit operations carried out, secondly on the basis of mill type, and thirdly according to the processing sequences applicable to the major fibre types. No single basis provides a complete and definitive classification: in each case other relevant factors must be cross-correlated, for example in describing a sector of the Industry by mill type, other factors such as fibre type(s), the range and type of processing operations carried out, the end-products produced and even the type of machinery employed may all significantly affect the water intake and effluent generation to be expected.

In Section 2.2 the unit operations carried out by the Industry are described, and in Section 2.3 the major types of mill are described briefly as this gives a useful background for describing various sectors of the Industry. In Section 2.4 the sequences of unit operations involved in the processing of the major fibre types are outlined. Water intake, water use and effluent generation in the Industry are discussed in Chapter 3 on the basis of unit operations, as this approach is best suited to assessing the relative efficiencies (with regard to water and waste-water management) of comparable operations carried out at different textile mills.

2.2 Unit operations in textile processing

Many water-using steps in textile processing are common to a number of different fibre types, although the specific water use may vary according to fibre type, equipment, methods, and other factors. The major unit operations are described briefly in the following, with reference to their application as appropriate to different fibre types:

Opening, picking and blending are operations where bales of raw fibre are opened and picked to remove trash, seed and short fibre before being blended together (e.g. cotton/polyester) as required.

Combing and carding are operations where the fibre is cleaned, the long axes of the fibre are aligned, and further removal of short fibre takes place.

Spinning is a mechanical operation in which the fibres are drawn out into yarn and a twist is introduced to produce yarns for dyeing, finishing, knitting, or weaving, as required.

Sizing is the coating of yarns with a film of the sizing agent to provide protection from abrasion during weaving, to strengthen the yarn and to reduce yarn hairiness. Sizing agents used may be either natural or synthetic e.g. starch, modified starch compounds, polyvinyl alcohol, carboxymethyl cellulose, and mixtures of these.

Weaving is a dry process but is normally carried out under controlled high-humidity conditions to minimize yarn breaks on the loom, as the size film is flexible under such conditions.

Singeing of woven fabric is carried out to remove surface hairiness.

Knitting is also a dry process but knitting oils are applied to reduce friction and breaking of the yarn, and these oils (typically 0,5 to 3,0% m/m) have subsequently to be removed for further processing.

Desizing is the removal, after weaving, of the sizing agent applied. Enzymatic degradation is used to desize starch sizes, which cannot therefore be effectively recovered, while synthetic sizes can be recovered *inter alia* by membrane techniques. Wool is not desized, the sizing agent remaining on the fibre.

Dyeing is carried out on either the stock, yarn or fabric (knitted or woven) using various classes of dyestuff (for example direct, sulphur, pigment, vat, reactive, acid, disperse or cationic) as appropriate for the fibre concerned. The dyeing methods used may be either batch or continuous, may be carried out using a variety of equipment types (e.g. jig, jet, beam) and may be carried out with the fabric either in rope or in open-width form. Where blends are dyed, the fibres concerned are dyed separately because of the differences in their chemical composition. Depending on the combination of factors involved, water use at the dyeing stage varies widely. The chemical conditions under which the dyestuff is applied depend on the fibre type and the dyestuff type, and the resultant effluents thus also vary widely in terms of pH, dissolved solids and colour.

Printing of fabric is carried out using similar classes of dyestuff as used for the dyeing of yarn or fabric, but applied as a paste using, for example, hydrocarbons or alginates which are then dried (baked), fixed and washed off. Ranked generally in order of decreasing water use and effluent generation, printing methods range from conventional printing using diffusing dyes (direct, acid metal complex, reactive, disperse, vat and cationic) to pigment printing (with or without hydrocarbons) to transfer printing.

Scouring processes are used extensively to remove inherent or added impurities in raw fibre or fabrics. Wool is scoured using sodium carbonate and detergents. Cotton is scoured with hot (boiling) sodium hydroxide solutions and detergents to remove naturally occurring waxes and added processing oils. Polyester is scoured at lower temperatures (typically 60°C) and under more mild alkaline conditions to avoid excessive saponification of the fibre. Polyester/cotton blends are scoured under intermediate alkaline and temperature conditions. Scouring effluents are generally alkaline and high in sodium content.

Mercerizing is a treatment given to cotton fibre, under tension, using a concentrated sodium hydroxide solution at 22 to 26% m/m, to improve various properties of the fibre such as reflectance, lustre, tear strength, dyeability and dimensional stability. The tensioned cotton is immersed in the mercerized liquor, generally at 13 to 15°C but sometimes at elevated temperatures (up to 40°C). After mercerizing the fibre is rinsed extensively and neutralized using a weak organic acid such as acetic or formic acid. Mercerizing effluents consist of the rinse waters and are generally characterized by being highly alkaline ($pH \geq 13,5$), high-temperature (up to 100°C, due to the exothermic nature of the process) and with high residual concentrations of sodium hydroxide (27 to 80 g/ℓ has been reported[4]).

Bleaching is carried out using oxidizing agents such as hydrogen peroxide or hypochlorite solutions with the aim of reducing the natural colour of the yarn or fabric.

Finishing operations include various processes to improve the stability and quality of handle of the fabric (e.g. softening, crease resistance) and to impart special properties (e.g. stain resistance, flame proofing, etc.)

The unit operations described briefly above are applied as indicated to various fibre types. Two unit operations which are used only for wool processing are:

Carbonizing, where the wool is treated with sulphuric acid to remove residual organic matter; and

Fulling, where the wool is mechanically worked wet, with the addition of detergents, to improve the stretch characteristics of the material (worsteds and wool blends are not fulled).

2.3 Textile mill types

The main types of textile mill include the following:

(a) **Dry processing mill** (Figure 2.2)

At dry processing mills, raw fibre stock is taken in to produce either spun yarn or woven fabric for forwarding respectively to stock yarn dyeing and finishing mills or woven fabric finishing mills. In the RSA, dry processing mills are usually integrated on the same site with further processing mills.

(b) **Woven fabric finishing mill** (Figure 2.3)

Woven fabrics involving cotton are sized at the dry processing mill stage. At woven fabric finishing mills, extensive pretreatment is then carried out to prepare the fabric for dyeing or printing, where it is common for mills to carry out both processes. Finishing operations carried out depend on the fibre type and the properties required, for example woven fabrics involving cotton are usually finished with a resin/softener combination to give crease-resistant properties, whereas woven synthetics are usually just softened.

(c) **Knit fabric finishing mill** (Figure 2.4)

Knitted cotton fabric is prepared for dyeing and/or printing similarly as for woven cotton fabrics, except that different equipment is used and the fabric is usually not resin-finished. Knitted synthetics are given a light scour to remove knitting oil and are then dyed or printed. A softener is applied during finishing.

(d) **Wool scouring mill** (Figure 2.5)

Raw wool contains a high proportion of impurities (typically 60% by mass) including dirt, suint, grease and vegetable matter, and wool scouring thus produces an effluent with very high organic and inorganic pollutant loads. In the RSA, wool scouring is carried out using sodium carbonate and detergents in sequential bowl scouring stages to clean the wool. Water use and effluent management in wool scouring mills have been dealt with in a separate WRC project[6].

(e) **Wool finishing mill** (Figure 2.6)

The wool top is generally blended and scoured to remove oils, etc., before dyeing of the fibre, which may be carried out on the stock, yarn or fabric. Most wool finishing mills also produce wool/synthetic blends. 100% woollen goods are fulled in the presence of detergents to improve dimensional stability of the material. Worsteds and wool-synthetic blends are not fulled.

(f) **Stock and yarn dyeing and finishing mill** (Figure 2.7)

Cotton yarns are bleached and occasionally mercerized, before being dyed and softened, while synthetic yarns are given a light scour before being dyed and softened.

(g) **Carpet mill** (Figure 2.8)

Carpets are either woven with pre-dyed yarn or are dyed or printed after weaving, using techniques appropriate to the type of fibre involved. After being washed and dried, a later foam backing is often applied to stabilize the pile.

(h) **Other**

Contract dyehouses take in a variety of fibre and fabric types and carry out a wide range of dyeing and finishing operations using batch or continuous processing methods.

2.4 Processing sequences for major fibre types

Major steps in the processing of cotton are illustrated in Figure 2.9, which shows also at which unit operations liquid effluents and solid wastes are produced.

Major steps in the processing (excluding scouring) of wool are illustrated in Figure 2.10, showing also at which unit operations liquid effluents and solid wastes are produced.

Major steps in synthetics processing are illustrated in Figure 2.11. Synthetics used commonly in the Industry to produce a wide range of products include polyester, acrylics, viscose (rayon) and nylon. The processing requirements, in particular for dyeing, vary widely due to the differing chemical compositions of the various synthetic fibres. Where blends are produced, as in polyester-cotton blends, the two fibres are either dyed separately, i.e. two dyeing effluents are generated, or the blend is dyed, generating a single dyeing effluent.

Production of garment, accessory and haberdashery materials involves a wide range of processes, sometimes including dyeing and finishing and therefore with a significant impact on water and effluent. Large numbers of workers are employed in this sector of the textile industry, and significant quantities of solid waste (and sometimes liquid effluents) are produced in some of the processing activities involved.

FIGURE 2.2 SCHEMATIC DIAGRAM OF DRY PROCESSING MILL

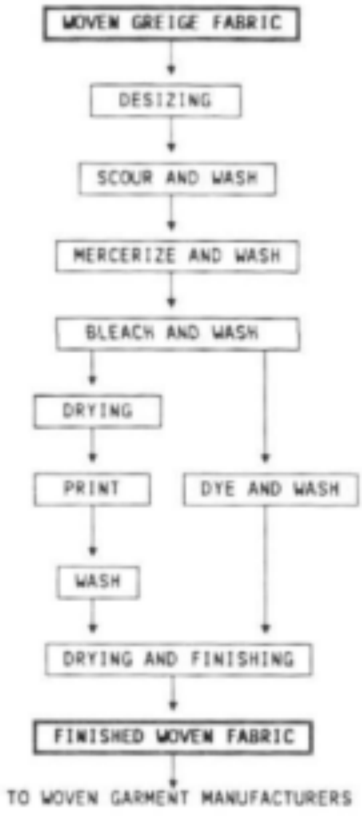

FIGURE 2.3 SCHEMATIC DIAGRAM OF WOVEN FABRIC FINISHING MILL

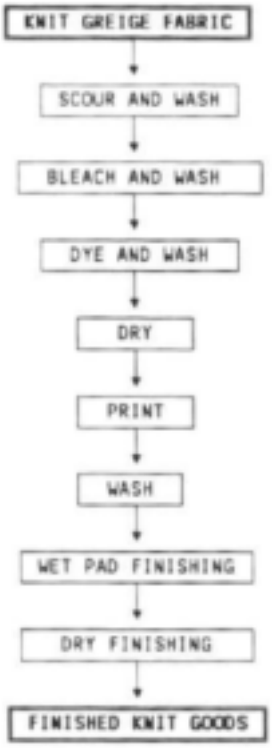

FIGURE 2.4 SCHEMATIC DIAGRAM OF KNIT FABRIC FINISHING MILL

FIGURE 2.5 SCHEMATIC DIAGRAM OF WOOL SCOURING MILL

FIGURE 2.6 SCHEMATIC DIAGRAM OF WOOL FINISHING MILL

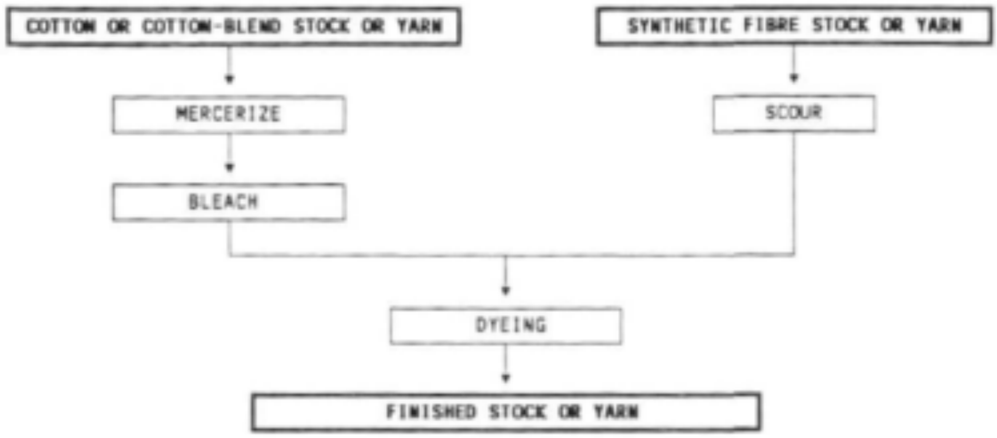

FIGURE 2.7 SCHEMATIC DIAGRAM OF STOCK OR YARN DYEING AND FINISHING MILL

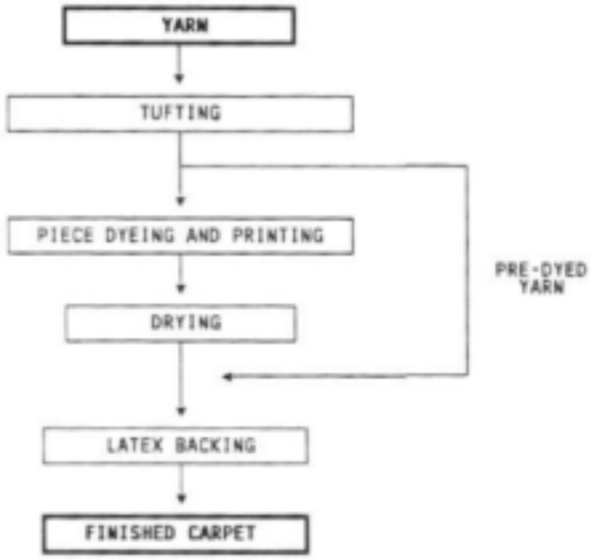

FIGURE 2.8 SCHEMATIC DIAGRAM OF CARPET MILL

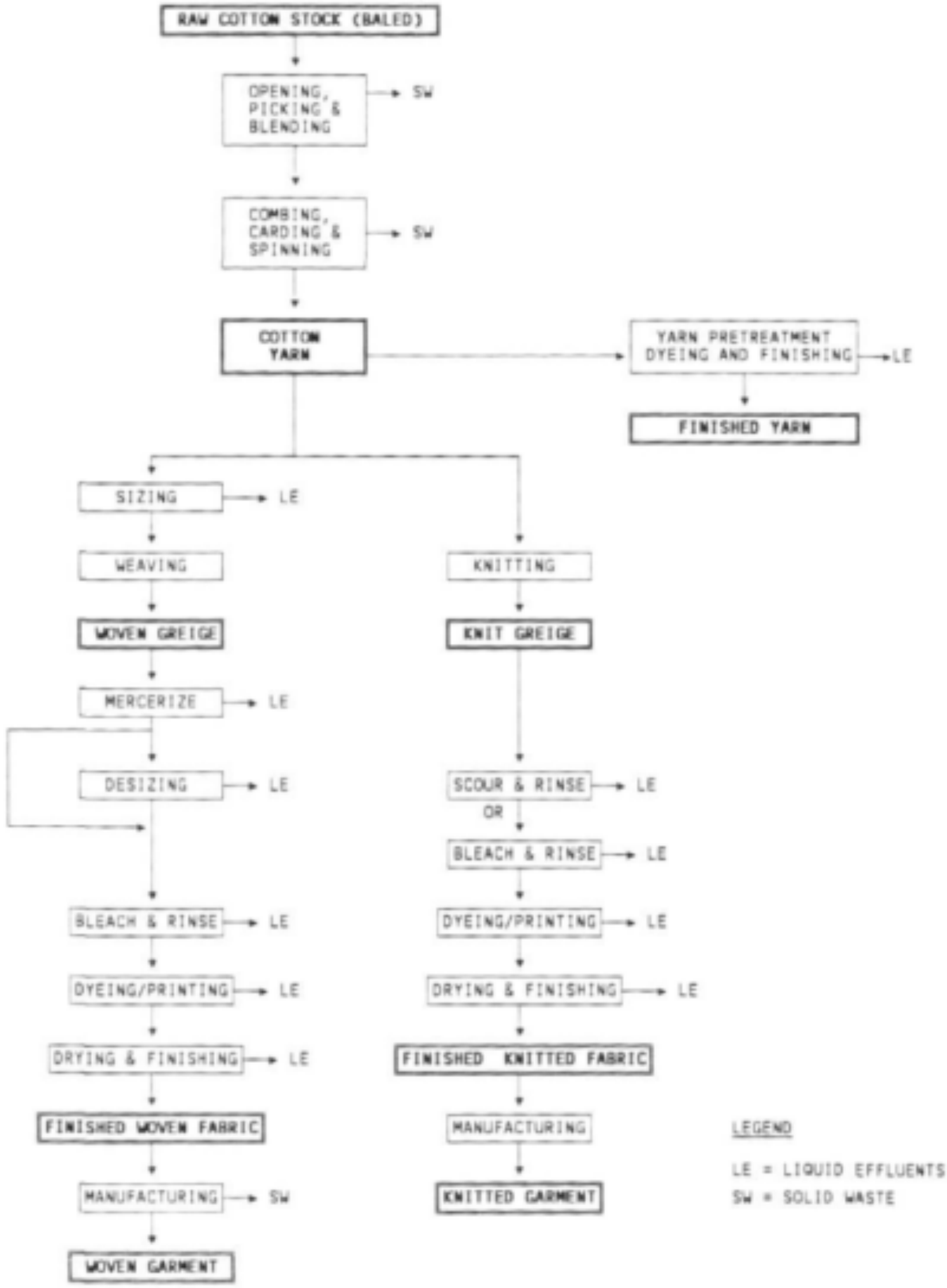

FIGURE 2.9 MAJOR STEPS IN COTTON PROCESSING

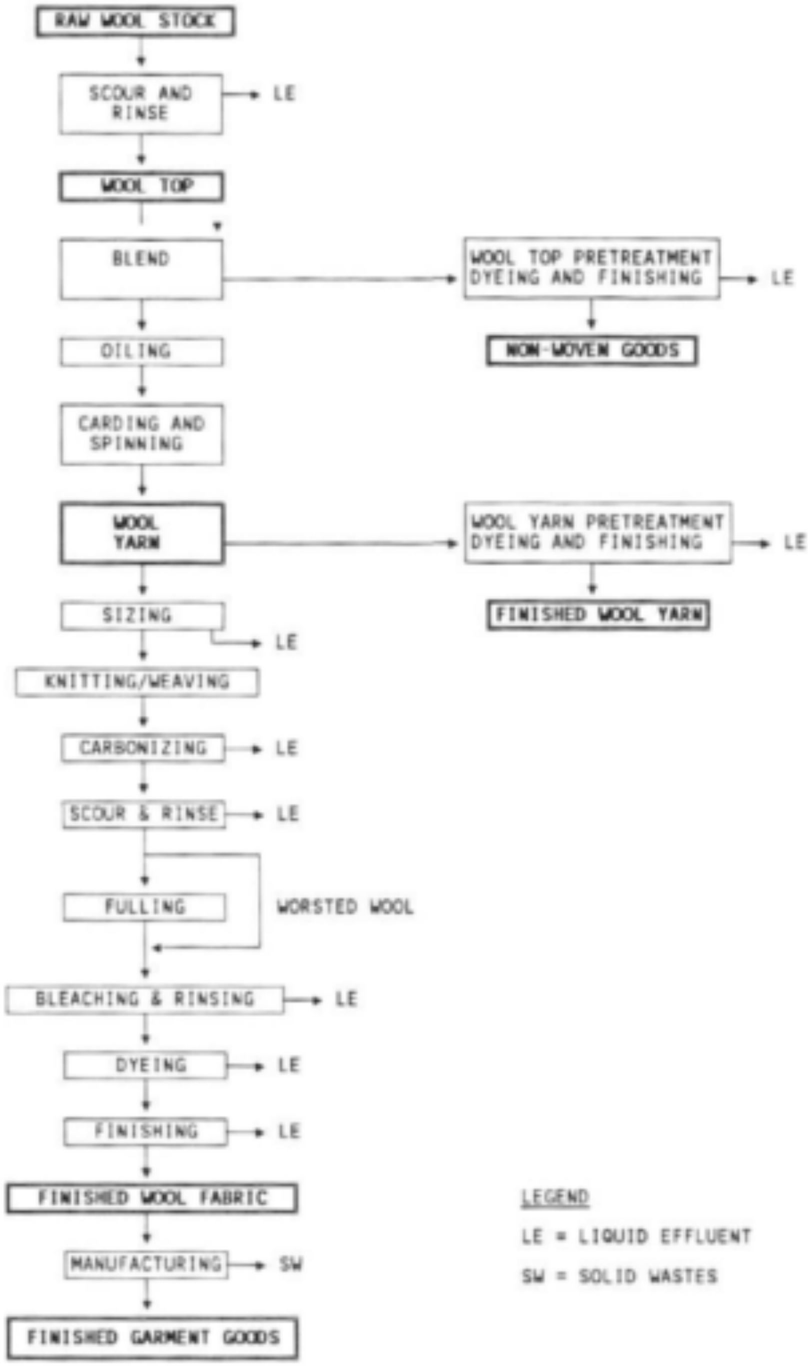

FIGURE 2.10 MAJOR STEPS IN WOOL PROCESSING

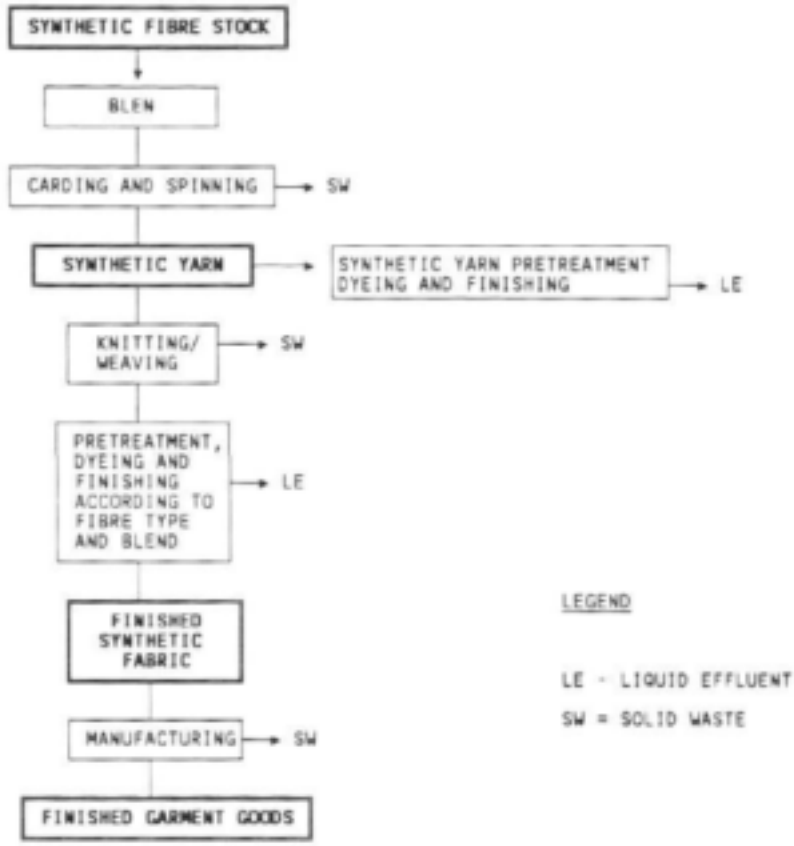

FIGURE 2.11 MAJOR STEPS IN SYNTHETICS PROCESSING

3 SUMMARY OF WATER USE AND EFFLUENT GENERATION IN THE INDUSTRY

3.1 Introduction

The textile industry is extremely diverse and varied, not only vertically (e.g. mill type and final products) and horizontally (e.g. fibre type, fibre form, method of dyeing, dyeing equipment, pre- and post-treatment requirements, etc.) but also time-wise by season and according to market and fashion trends. Some factories surveyed produce essentially a single fibre type or blend, on a continuous basis, while in others (e.g. commission dyehouses) the materials handled and methods can vary hourly on a batch-wise basis.

A number of projects sponsored by the WRC have been aimed at identifying water use and effluent generation in various sectors of the textile industry. In the present project, a cross-section of textile mills was surveyed, as summarized in Appendix A. The results were found to be generally within the range reported previously[2, 3, 4, 5, 6, 7, 10].

3.2 Water intake and water use

The overall water intake at a textile plant may be broken down into water used for processing, for utilities and for amenities as follows:

- Water use for processing depends on a number of factors (e.g. fibre type, type of mill, dye type, dyeing and/or printing processes, dyeing and/or printing equipment, etc.) and is best described in terms of unit operations.

- Water use for utilities (water treatment, boilers, cooling, steam drying, air conditioning, humidifying, etc.), depends on site specific factors, but is typically 5 to 10% of the overall water intake.

- Water use for amenities (ablutions, gardens, etc.) is significantly affected by the number of workers employed on site, and, in "dry processing" operations such as garment manufacture, can account for up to 100% of the overall water intake.

Because of the factors indicated above, the water use for processing, amenities and ablutions respectively at different textile plants can constitute very widely varying proportions of the water intake, as illustrated in Figure 3.1. Similarly, where wet processing is carried out, the overall specific water use (SWU, ℓ/kg) for processing will depend on both the nature and the water-efficiency of the wet-processing operations involved. The SWU for processing can thus vary widely, as illustrated in Table 3.1 and as detailed in other WRC studies [2-5].

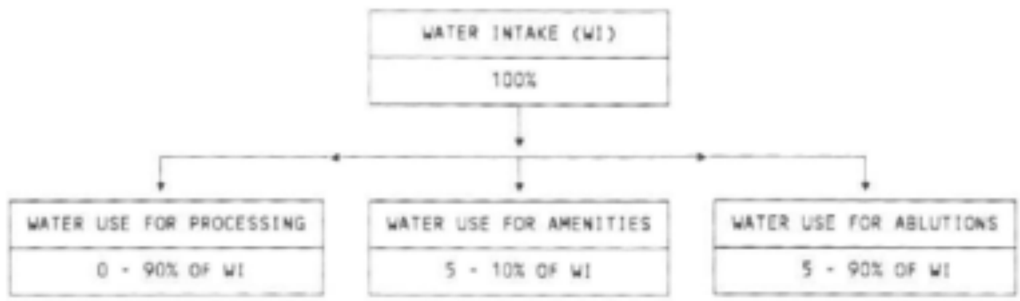

FIGURE 3.1 BREAKDOWN OF SPECIFIC WATER USE FOR PROCESSING

TABLE 3.1 RANGE OF SPECIFIC WATER USE (SWU) VALUES FOR WET-PROCESSING STEPS

PROCESS STEP	RANGE* IN SWU FOR PROCESSING STEPS (ℓ/kg)	
	LOW VALUE	HIGH VALUE
Singeing	1	2
Sizing - woven goods	1	2
Desizing	5	15
Scouring	4	25
Mercerizing	6	17
Bleaching	10	100
Dyeing	9	330
Printing	3	33
Washing-off prints	29	505
Finishing	13	134
Overall (typical)*	100	300

* Note that for some types of fibre or product, one or more of the processing steps indicated may not be carried out at all, in which case the lower limit would be zero. The "overall (typical)" SWU values given are thus not obtained by summing the individual values in Table 3.1.

From Table 3.1, it may be noted that the largest area of variation in processing SWU values is in dyeing and printing, where the following factors significantly affect the SWU for dyeing and/or printing:

- the fibre types and blends being processed, and their proportions;
- the fibre form (stock, yarn, woven fabric, knitted fabric, piece goods);
- pretreatment and post-treatment requirements.
- the dyeing mode (batch, continuous);
- dye class, equipment and the liquor ratios employed;
- the range and depth of shade;
- the degree of re-processing involved;
- production variations due to fashion demands, colourage and seasonal changes.

For any particular textile factory carrying out a set sequence of wet-processing operations, the overall SWU for processing may be derived by summing the SWU values for the individual processing steps. A table of SWU breakdown, similar in form to Table 3.1 but reflecting only the process water uses actually involved can then be constructed. An example is given in Table 3.2 for various wet-processing operations at a mill producing a 50/50 polyester/cotton blend and carrying out both dyeing and printing[2].

TABLE 3.2 EXAMPLE OF PROCESSING SWU VALUES AT 50/50 POLYESTER/COTTON MILL

PROCESS	SWU (ℓ/kg)	% OF PROCESSING SWU
Singeing	1,2	1,0
Sizing	12,5	8,2
Desizing	12,5	8,2
Scouring	25,0	16,5
Mercerizing	16,7	11,0
Bleaching(1)	16,7	11,0
Dyeing(2)	42,0	27,7
Printing(3)	12,5	8,2
Finishing	12,5	8,2
Processing SWU	151,6	100,0

Notes: (1) Based on woven goods; other values[2] are 83 ℓ/kg for knit goods and 100 ℓ/kg for yarn goods.
(2) Based on various types of dyeing for woven goods.
(3) Based on pigment dyeing of woven goods; other values[2] range up to 33 ℓ/kg for vat dyeing.

From Table 3.2 it may be noted that dyeing and printing account for a large proportion (43% in this case) of the SWU for processing. The SWU for dyeing and printing will vary from case to case, and in some instances, (e.g. batch dyeing in a commission dyehouse), even from hour to hour.

In view of the considerations presented, it is concluded that the Industry does not have a meaningful national average specific water intake (NASWI) value. It has been estimated[7] that the water intake by the Industry is around 30 000 Mℓ/a. Applying this figure to the annual consumption of cotton, polyester, acrylic, nylon, viscose and wool by the Industry in the RSA in 1990 (total 219 350 t/a, Table 1.1), a national average specific water intake of around 137 ℓ/kg is indicated. As an example of the differences that can arise, however, at one factory a change from 60% batch processing (40% continuous) to 8% batch processing (92% continuous) was largely responsible for a reduction in SWI from 140 to 95 ℓ/kg. As indicated previously, such factory-specific or process-specific factors are more significant for a particular factory at a particular time than an NASWI value.

3.3 Effluent

Apart from evaporative losses, water is generally used non-consumptively in the wet processing operations in textile processing, i.e. the effluent volume generated is approximately equal to the water use at the processing step concerned. Specific effluent volumes (SEV) are thus typically 80-90% of the corresponding SWU value, which depends on the processing regime concerned (Section 3.2).

From survey data obtained during a number of projects[2,3,4,10] carried out for the WRC, Table 3.3 summarizes pollutant loads for various wet preparation, dyeing and finishing operations in terms of SEV and SPL (specific pollutant load) values. Note that effluent concentrations of particular pollutant parameters may be obtained from : Concentration (mg/ℓ) = 1 000 SPL/SEV.

TABLE 3.3 RANGE OF SPECIFIC POLLUTANT LOADS (SPLs) IN TEXTILE PROCESSING

UNIT OPERATION	SEV (ℓ/kg)	pH	SPL (g/kg)			
			COD	SS	TDS	COLOUR
Singeing	1,1	6 - 8	11	11	2	0
Desizing	12,5	6 - 8	77 - 425	5 - 77	20 - 55	0
Scouring	25,0	12	21 - 27	5	10	0
Mercerizing	16,7	12	3 - 14	5	72 - 77	0
Bleaching	16,7 - 100,0	10	3	4	20	0
Dyeing - cotton, direct	10,8 - 120,0	3 - 12	3,5 - 123,5	< 1	10 - 900	0,5 - 2,1
Printing	12 - 400	6 - 11	3 - 75	0,1 - 25	3 - 35	0,1 - 0,5
Finishing	12,5	6 - 8	12 - 120	12 - 30	17 - 22	N.D.

Note : The ranges of values given are not necessarily comprehensive, since extreme values for minor fibre types or operations are not necessarily included and may lie outside the ranges quoted.

There are wide variations in the SEV and SPL values for the various unit operations depending[8] *inter alia* on the fibre form (yarn, woven, knit), the mode of processing (batch, continuous), and the class of dyestuff (direct, reactive, vat, sulphur, dispersed, acid, basic). Examples[4] of the ranges in values that occur are : SEV values for wool dyeing may range from 38 to 152 ℓ/kg for wool top compared to worsted piece dyeing; SEV values for cotton dyeing may range from 80 to 120 ℓ/kg for different classes of dye; SPL values for dyeing 50/50 polyester/cotton may range from 57 to 192g TDS/kg for naphthol/dispersed versus reactive/dispersed dyeing.

The waste-water quality and specific effluent loads for factories surveyed are given in the Appendix (Tables A.3 and A.4 respectively) for a range of types of mill, fibre types and processing routes. In some cases, where the processing operations are relatively constant and continuous, the average values are generally representative of the factory. In other cases, where production processes vary significantly, the results obtained are indicative only of the effluent quality during the survey period; widely different results could be obtained at other times.

In addition to the common pollutant parameters (COD, TDS, TDIS and SO_4) identified in Tables A.3 and A.4, dyehouse effluents can also contain significant concentrations of heavy metals depending on the particular dyestuff employed. An example[4] for a particular dyehouse is given in Table 3.4.

TABLE 3.4 EXAMPLE OF HEAVY METAL CONCENTRATIONS IN A DYEHOUSE EFFLUENT

HEAVY METAL	MEAN (mg/ℓ)	RANGE (mg/ℓ)	STANDARD DEVIATION
Cadmium	0,12	-	-
Chrome	0,85	0,3 - 2,3	1,0
Copper	1,08	0,1 - 1,6	0,8
Iron	2,10	0,4 - 3,8	-
Mercury	0,85	-	-
Lead	0,27	-	-
Zinc	0,77	0,1 - 1,2	0,6

It may be noted that if accurate data on process chemical quantities, liquor ratios, and absorption and fixing ratios on the fibre are available for a particular process, the theoretical pollutant load in the effluent may be calculated. This approach may have useful application in particular cases.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Water intake

SWI values observed in the textile industry in the RSA range from 95 to 459 ℓ/kg. In view of the diverse nature of the Industry in terms *inter alia* of the fibre type processed, fibre form, pretreatment requirements, dyeing mode, dyeing methods, equipment, printing techniques and finishing requirements, a narrow range in SWI values cannot be realistically expected.

Equally, it is not realistic to set specific targets for SWI for the Industry as a whole. This would require a large number of process-specific target conditions, which would in practice be unworkable for large sectors of the Industry.

It is therefore concluded that individual textile processing facilities must begin by developing their own overall processing SWI values based on the SWU values applicable to the particular processing steps being carried out, as described in Section 3.2. Once sufficient data has been obtained, meaningful SWU and SWI targets can be set for the processes and factory.

It should be noted that in the water-scarce, South African context, a reduction in SWI could in many significant cases be either the only or the most cost-effective means towards ensuring an adequate water supply for future expansion of production.

In order to utilize the water intake more efficiently, two parallel requirements must be met, namely:

- a suitable water management plan must be formulated and implemented, and
- methods of reducing water use must be identified and implemented.

4.2 Water management

Water management should aim firstly at reducing arbitrary variations in SWU and SWI values, and secondly at reducing the absolute SWU and SWI values. A suitable approach to water management for the textile industry is as follows:

- Available water resources and their cost, including the cost of treatment, if required, must be assessed. Due account should be taken of expansion plans.
- Provision must be made to monitor comprehensively and accurately the existing water intake and water use. This entails *inter alia* developing proper drawings of the water reticulation system, rationalization of the water reticulation system (elimination of unneces-

sary cross-links, etc.), identification of all water using points, and the installation and maintenance of water meters with recorders where necessary.

- Having installed an adequate metering system so that water intakes can be properly accounted for, an appropriate routine system for monitoring individual water uses and constructing a water balance must be adopted and implemented.

- The data obtained should be used by management to identify excessive water uses, wastages and extraordinary occurrences and, very importantly, to ensure that theoretical minima (e.g. machine settings, process requirements, etc.) are routinely attained.

- Operating personnel should be involved in the water management programme and be made aware of the importance of water conservation.

- Opportunities for reducing specific water intake and improving the efficiency of water use should be identified and acted upon.

4.3 Reduction in water use

Methods of reducing water use, i.e. improving water efficiency, include the following:

- Elimination where possible of batch equipment in favour of continuous processing (in a case study, an increase from 40% continuous processing to 92% continuous processing was largely responsible for a reduction in SWI from 140 to 95 ℓ/kg).

- Use of water-efficient processes and equipment.

- Automated regulation of water flow on stoppage of machines.

- Selection of water-efficient dyeing methods.

- Further development of solvent-dyeing processes as opposed to aqueous-media dyeing.

- Proper design of rinsing operations according to engineering principles so as to provide maximum water-efficiency.

- Continued and extended use of counter-current continuous rinsing techniques.

- Cascaded re-use of slightly contaminated final rinse waters for purposes requiring lesser water quality standards e.g. cooling.

- Elimination of live steam heating and the provision of condensate return systems.

- Consideration of water reclamation for re-use from effluents, for example by membrane techniques.

- The introduction of closed-loop systems for size recovery from desizing effluents (where applicable), to reduce water use and pollutant loads in sizing/desizing.

4.4 Effluent generation

The quantity (SEV) and quality (SPL/SEV) of textile effluents vary widely due to the diversity of processing and other variables concerned. SEV values ranging from 106 to 413 ℓ/kg were observed. SPL values ranging from 9 to 352 g COD/kg, 101 to 762 g TDS/kg, 62 to 660 g TDIS/kg and 19 to 225 g SO_4/kg were determined, and high levels of heavy metal contamination were noted in some dyehouse effluents.

For the same reasons cited for water intake (Section 4.1), it is impracticable because of the diverse nature of the textile industry to set universal SEV or SPL targets. A similar approach as described for SWU and SWI should be adopted to develop suitable SEV and SPL targets. Proper account should be taken of the following characteristic features of textile effluents:

- High volumes arising from the extensive wet processing methods involved.

- High acidity and/or basicity, frequently with rapid and wide swings in pH as different effluents predominate in the final effluent.

- High levels of dissolved solids.

- High levels of inorganic salts.

- Moderately high organic (e.g. COD) levels but relatively low biodegradability.

- High colour, depending on the dyeing process used.

- The possible presence of heavy metals, potentially at unacceptably high concentrations or mass loadings.

The textile industry generally has difficulty in meeting waste-water discharge limits, particularly with regard to dissolved solids, ionic salts, pH, colour and, sometimes, heavy metals. Even where local discharge limits are met, the waste water discharged often poses problems to the treatment authority because of its limited tractability and variable quality.

It should be noted that effluent discharge tariffs have increased rapidly in the recent past, a trend that is set to continue in the future. This is of significance to the textile industry in view of the large effluent volumes generated and the high effluent discharge costs attracted, both normally and as penalties for infringements of permissible discharge limits.

4.5 Effluent management

Pollutant loads in final effluents can be minimized by limiting and controlling pollutants at source. Areas that should be given attention include the following:

- Segregation and appropriate separate treatment of high-strength effluents such as dyeing, mercerizing, scouring and dyebath effluents.

- Dry collection techniques for chemical spillages, rather than flushing to drain.

- Minimizing effluent volume by reducing water use, while concomitantly reducing pollutant losses to drain to ensure that effluent quality discharge limits are not exceeded.

- Identification and control or elimination of pollutant sources that pose special discharge problems, for example detergents, oils, solvents, dyes and finishing agents.

- Substitution wherever possible of less aggressive processing chemicals as alternative for toxic or highly polluting chemicals.

- Proper inventorying and control of the large quantities of chemicals routinely handled on site.

4.6 Waste-water treatment

On-site effluent treatment methods that can be practised using established technology to achieve significant improvement in the final waste-water quality discharged from textile processing operations include the following:

- Sodium hydroxide recovery from highly alkaline mercerizing effluents; in addition to reducing the excessively high pH of some final effluents, the high sodium content of the final effluent is also reduced.

- Fine screening to remove lint etc. to reduce suspended solids in the effluent.

- Balancing and/or storage of the final effluent to smooth out *inter alia* variations in quality; an additional benefit is available from some municipalities in that if the balanced effluent is discharged at night with proper flow control and recording, a substantial reduction in the effluent discharge tariff is offered.

- Adjustment of the pH of the waste water discharged using adequate pH control and chemical dosing systems, to ensure permissible discharge limits are not exceeded.

- Consideration can be also be given to the use of advanced waste-water treatment systems for economically treating individual effluent streams, to reduce the pollution loads discharged as well as offering potential benefits in terms of recovered and re-useable materials.

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APPENDIX

TABLE A.1 SUMMARY OF TEXTILE MILLS SURVEYED

FACTORY	FIBRE RANGE	CLASSIFICATION	PRODUCTION (kg/a)
A	Poly-cotton, cotton	WFF	> 2 000 000
B	Cotton	WFF	942 300
C	Cotton, synthetics	WFF	1 413 000
D	Cotton	KFF, GAR	1 056 000
E	Cotton, synthetics	WFF	1 932 000
F	Synthetics, cotton	WFF	
G	All	KFF, COM, GAR	351 398
H	All	COM	8 250 000
I	Synthetics, cotton	KFF	1 993 500
J	Cotton	ACC, HAB	686 700
K	Wool, synthetics	WFF, WOR	1 250 000
L	Polyester-cotton	WFF	N/A
M	Cotton, synthetics	ACC	N/A
N	All	GAR	980 000
O	Wool, synthetics	CAR	N/A
P	Cotton, synthetics	COM	N/A
Q	Cotton, synthetics	WFF	N/A
R	Cotton, synthetics	WFF	N/A

* Codes:

WFF = woven fabric finishing;
COM = commission dyehouse;
ACC = accessories manufacture;
WOR = worsted fabric finishing;
KFF = knit fabric finishing
GAR = garment manufacture;
HAB = haberdashery manufacture;
CAR = carpet manufacture

Note: N/A indicates representative production throughput not available.

TABLE A.2 SPECIFIC WATER INTAKE AT TEXTILE MILLS SURVEYED

FACTORY	ANNUAL WATER INTAKE (m^3)	ANNUAL PRODUCTION (kg)	SWI (ℓ/kg)
A	568 800	> 2 000 000	284
B	1 321 112	942 300	140
C	391 978	1 413 000	277
D	375 840	1 056 000	356
E	291 837	+ 1 932 000	< 151 (95)
F	446 806	N/A	N/A
G	127 756	351 398	364
H	990 000	8 250 000	120
I	357 209	N/A	N/A
J	118 800	686 700	173
K	158 400	1 320 000	120
L	33 044	72 000	459
M	198 000	N/A	N/A
N	446 400	N/A	N/A
O	300 000	N/A	N/A
TOTAL	3 188 567	18 023 348	
MEAN	-	-	177

Points to note in relation to Table A.2 are:

(a) Where different fibres are processed at different times, for example in commission dyehouses, an average SWI over a period has been derived.

(b) Where only a fraction of production throughput is wet-processed (e.g. dyed and/or finished) on site, due account has been taken in determining the appropriate SWI value.

(c) Where a textile factory either exclusively or predominantly processes one fibre type to a relatively small range of finished products, the SWI value is more representative than in cases where factory operation is variable.

(d) In many textile factories, the material produced is affected by market and fashion trends and often varies seasonally as well, both of which affect water usage for processing and hence SWI.

(e) Equipment variations and efficiency affect the SWI value when comparing apparently similar operations.

TABLE A.3 WASTE-WATER ANALYSES AT TEXTILE MILLS

FACTORY	pH	COD (mg/ℓ)	TDS (mg/ℓ)	TDIS (mg/ℓ)	SO_4 (mg/ℓ)
A	9,3	1520	N.D.	1396	989
B	9,9	556	1296	N.D.	N.D.
C	6,9	1585	2231	1643	767
D	9,7	515	2467	2135	N.D.
E	11,15	2686	4850	2450	350
F	6,5	190	1454	954	295
G	8,5	81	950	587	181

N.D. = not determined

TABLE A.4 SPECIFIC EFFLUENT LOADS AT TEXTILE MILLS

FACTORY	PRODUCTION (kg/a)	SEV (ℓ/kg)	SPL (g/kg)			
			COD	TDS	TDIS	SO_4
A	+ 2 000 000	227	345	N.D.	317	225
B	942 300	115	64	409	N.D.	N.D.
C	1 413 000	222	352	495	365	170
D	1 056 000	309	159	762	660	N.D.
E	+ 1 932 000	113	304	548	277	40
F	351 398	226	43	349	216	67
G	8 250 000	106	9	101	62	19
H	686 700	138	N.D.	N.D.	N.D.	N.D.
I	1 320 000	113	N.D.	N.D.	N.D.	N.D.
J	72 000	413	N.D.	N.D.	N.D.	N.D.