The impact of a revised effluent colour standard on the operation of a textile mill in Hammarsdale: a business case study.

Submitted by

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Declaration:

I hereby certify that this dissertation was written by me and constitutes my own work. References have been provided to substantiate the factual content herein. All figures, tables and drawings have been denoted correctly and in accordance with the required protocols. The word count from page 1-1 to page 6-5 is 17 200.

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I thank the following persons and entities for having assisted me in the preparation of this dissertation:

The management and staff of Textile Mill A for assisting me subject to the following conditions;

i) that the real name of Textile Mill A not be disclosed in this dissertation;
ii) that trade secrets will not be divulged;
iii) that all figures supplied by Textile Mill A be indexed to a base year for comparison purposes;
iv) that no employee of Textile Mill A be quoted directly without the written permission of the Manufacturing Director; and
v) that a copy of the final dissertation, suitably bound and prepared, be given to Textile Mill A for record purposes.

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Executive summary:

At present, raw aqueous textile effluent produced by textile mills in Hammarsdale, KwaZulu-Natal is reticulated voluntarily to the Hammarsdale Wastewater Works owned by the eThekwini Municipality and operated by Ethekwini Water and Sanitation. Thereafter the treated effluent is discharged into the Sterkspruit River which flows into the Shongweni impoundment. The cost to these textile mills of treating this effluent is calculated using a trade tariff formula administered by Ethekwini Water and Sanitation.

In principle this arrangement is governed as follows;

- in the case of the textile mills, by Sewage Disposal Bylaws set by Ethekwini Water and Sanitation, and
- in the case of Ethekwini Water and Sanitation by a licence issued by the Department of Water Affairs and Forestry in terms of the National Water Act 36 of 1998. This Act prescribes a General Effluent Standard which specifies the quantity, quality and temperature of treated effluent which may enter a defined water resource such as the Sterkspruit River.

In practice however, the Hammarsdale Wastewater Works is not licensed by the Department of Water Affairs and Forestry and operates temporarily according to an Exemption Permit issued to Umgeni Water who owned and operated the Hammarsdale Wastewater Works until 2003. It is thus incumbent upon Ethekwini Water and Sanitation to obtain a licence from the Department of Water Affairs and Forestry in order to comply with the requirements of the National Water Act and be allowed to operate the Hammarsdale Wastewater Works on a permanent basis.

However, because of design limitations, the Hammarsdale Wastewater Works cannot remove the visible colour continuously and reliably from incoming raw textile effluent. The consequence of this is that the Sterkspruit River is often contaminated by coloured discharges from the Hammarsdale Wastewater Works.

In terms of the National Water Act this situation is illegal and must be remedied.

The approach adopted by Ethekwini Water and Sanitation has been to amend the Sewage Disposal Bylaws to oblige the textile mills (by the use of permits), by certain dates, to remove all, or most of the colour (to specified levels according to the test method used) from their effluent before it will be admitted to the Hammarsdale Wastewater Works for disposal. The costs of compliance will have to be borne by the individual textile mills.

This business case study explores the impact of this obligation on the business of Textile Mill A and examines solutions to the problem. After a review of the efforts of that company to conform with the concept of Cleaner Production, it was decided to perform an end-of-pipe effluent treatment trial using a skid mounted pilot-plant utilising an adsorption and flocculation mechanism followed by cold soda ash softening, 'polishing' through a column of granular activated carbon and the removal of calcium and magnesium through a cation exchange softening column.

The results obtained were;

- that the permit requirements of Ethekwini Water and Sanitation could be met,
- that a financial 'break-even' point could be achieved at the start of the project in 2005 should 43% of the treated effluent be recovered for reuse,
- that a realistic rate of water recovery would be 50% resulting in a positive contribution in present day terms (2004) of R65 000 in 2005 increasing to R1 377 000 in 2014,
- that this rate of recovery could be increased should a demineraliser be introduced into the treatment train, and
- that the project could be financed by a vendor on a Build, Own, Operate and Transfer basis with transfer of ownership to Textile Mill A occurring after 5 years.

The results of that trial showed that end-of-pipe effluent treatment is a viable option, technically and commercially, for Textile Mill A considering the current inclement trading conditions being experienced by the South African textile industry. It is also a means of assisting Ethekwini Water and Sanitation to comply with the requirements of the National Water Act.

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Acronyms:

ADMI	American Dye Manufacturers' Institute
AGOA	African Growth and Opportunity Act
B.A.T.	Best Available Techniques (see BREF)
BOD	Biological Oxygen Demand
BOOT	Build, Own, Operate and Transfer
BPEO	Best Practicable Environmental Option
BREF	A reference document on Best Available Techniques for the Textiles Industry prepared under the European Union Integrated Pollution Prevention and Control Programme
BSI	British Standards Institute
CAC	Command and control
CMA	Catchment Management Agency
COD	Chemical Oxygen Demand
CTELC	Clothing and Textile Environmental Linkage Centre
CY	Chinese Yuan
CP	Cleaner Production
CSIR	Council for Scientific and Industrial Research
DACST	Department of Arts, Culture, Science and Technology
DANCED	Danish Cooperation for Environment and Development
DANIDA	Danish International Development Assistance (previously DANCED)
DEAT	Department of Environmental Affairs and Tourism
DEEEP	Direct Estimation of Ecological Effect Potential
DTI	Department of Trade and Industries
DWAF	Department of Water Affairs and Forestry
EMAS	European Union Eco-Management and Audit Scheme
EMS	Environmental Management System
EOP	End-of-Pipe
ES	Environmental Scoreboard
ESTs	Environmentally Sound Technologies
eTM	eThekwini Municipality
EU	European Union
EU€	European Union Euro

EUEAS	European Union Ecolabel Award Scheme
EWS	Ethekwini Water and Sanitation
GAC	Granular Activated Carbon
GES	General Effluent Standards
GSP	Generalised System of Preferences
HWMC	Hammarsdale Waste Minimisation Club
HWW	Hammarsdale Wastewater Works
IPPC	Integrated Pollution Prevention and Control
IR	Indian Rupee
ISO	International Organization for Standardization
IT	Information Technology
JY	Japanese Yen
MWW	Mpumalanga Wasterwater Works
NEMB	National Environment Management Bill
NOSA	National Occupational Safety Association
NPCA	Norwegian Pollution Control Authority
NTU	Nephelometric Turbidity Units
NWA	National Water Act 36 of 1998
OECD	Organization for Economic Co-operation and Development
PA	Pinch Analysis
pH	A measure of the acidity or alkalinity of an aqueous solution over a range from 1 (acidic) to 14 (alkaline) and 7 (neutral)
PPP	Polluter Pays Principle
SDBs	Sewage Disposal Bylaws
SIDA	Swedish International Development Cooperation Agency
ss	Settleable Solids
SS	Suspended Solids
TD	Taiwanese Dollar
TMA	Textile Mill 'A'
TTF	Trade Tariff Formula
UK	United Kingdom
UK£	British pound
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

USA	United States of America
US$	United States Dollar
UW	Umgeni Water
WPA	Water Pinch Analysis
WRC	Water Research Commission
WSA	Water Services Act 108 of 1997
ZAR	South African Rand

Glossary:

Acetate fibre The generic name for cellulose acetate fibres in which less than 92% but at least 74% of the hydroxyl groups are acetylated. These fibres were formerly referred to as *diacetate*.

Acid dye An anionic dye characterized by its substantivity for protein fibres and polyamide fibres and usually applied from an acidic or neutral dyebath.

Acrylic fibre The generic name for fibres made from a synthetic linear polymer that consists of at least 85% (m/m) of acrylonitrile units or acrylonitrile copolymers.

Aerobic digestion The biodegradation of organic matter in the presence of oxygen.

Anaerobic digestion The biodegradation of complex organic substances in the absence of oxygen to yield carbon dioxide, methane and water.

Auxiliaries Chemicals and substances such as dispersing agents and anti-foaming agents.

Basic dye A cationic dye characterised by its substantivity for acid types of acrylic fibres.

Beam dyeing The dyeing of **yarn**, wound in the form of a **warp** sheet or a fabric on a perforated beam.

Bioaccumulation How the substance accumulates in the environment.

Biodegradable Capable of decomposition by biological means.

Catchment In relation to a watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.

Chemical Oxygen Demand

Is the amount of oxygen required to chemically oxidize organics in a liquid. It is used to measure the organic strength of domestic and industrial wastes, based on the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acidic conditions.

Chromophore, chromophoric

A molecular group capable of selective light absorption resulting in colouration of aromatic compounds.

Cleaner production A broad term encompassing the concepts of waste minimisation, waste avoidance, pollution prevention and other similar terms. Cleaner production is the continuous use of industrial processes and products and services to prevent pollution and reduce wastes at their source.

Colour The characteristic of the visual sensation that enables the eye to distinguish differences in its quality, such as may be caused by differences in the spectral distribution of light rather than by differences in special distribution or fluctuations with time.

As above, but applied directly to the stimulus or the source (primary or secondary) giving rise to the sensation. (For brevity, the stimulus is often referred to as the colour).

The property of an object or stimulus or quality of visual sensation, distinguished by its appearance of redness, greenness, etc, in contradistinction to whiteness, greyness, blackness (i.e. chromatic colour is contradistinctive to achromatic colour).

Conservation In relation to a water resource means the efficient use and saving of water, achieved through measures such as water saving devices, water efficient processes, water demand management and water rationing.

Detergent A substance that assists in the removal of dirt by emulsification or dissolution of the dirt particles and normally has the power of suspending the dirt in the cleansing liquid.

Direct dye An anionic dye having substantivity for cellulosic fibres when applied from an aqueous dyebath containing an electrolyte.

Disperse dyes A class of water-insoluble dyes introduced originally for dyeing cellulose acetate and usually from fine aqueous suspensions.

Dye A colourant that has substantivety for a substrate, either inherent or induced by reactants.

Dyeing The treatment with a dye to obtain a persistent modification in the colour of a fibre.

Dye liquor The liquid that contains the dye and the reagents necessary for dyeing.

Exhaustion A measure of the quantity of dye that becomes fixed to the fibre being dyed. The unexhausted dye flows into the effluent stream.

Fabric	A manufactured assembly of fibres or yarns (or both) that has substantial surface area in relation to its thickness, and sufficient mechanical strength to give the assembly inherent cohesion.
Fastness	The property of resistance to the agency named (e.g. to washing, light, rubbing, cracking, gas fumes etc).
Fenton's reagent	Fe^{2+}: H_2O_2
Fibre	A unit of matter characterized by flexibility, fineness and a high ratio of length to thickness.
Flocculation	An agglomeration of finely divided or colloidal particles.
Jet dyeing	A tubular machine utilizing water jets to circulate fabric in a dye bath.
Jig	An open vat which passes full width cloth from a roller through a dye liquor and then on to another roller.
Kermel®	A patented flame resistant synthetic polyamide-imide fibre made by Rhodia.
Kevlar®	A du Pont patented high strength synthetic fibre comprsisting of poly (p-phenyleneterephthalamide) used in the manufacture of impact resistant fabrics.
Liquor ratio	The ratio between the mass of liquor employed in any treatment and the mass of fibrous material treated.
Nylon fibre	The generic name for fibres made from a synthetic linear polymer in which the linkage of the simple chemical compound or compounds used in its production takes place through the formation of amide groups.
Parachute cloth	A close-weave, lightweight synthetic fibre or silk fabric with high bursting and tearing strengths.
Photodegradation	Degradation caused by the absorption of light (particularly ultraviolet light) and consequent chemical reaction.
Pollution	Means the direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used, or harmful or potentially harmful to the welfare, health or safety of human beings or to any aquatic or non-aquatic organisms or to resource quality or to property.

Polyester fibre	The generic name for fibres made from a synthetic linear polymer that contains, in the chain, at least 85% (m/m) of an ester of a dihydric alcohol and a terephthalic acid, e.g. poly(ethyleneterephthalate).
Reactive dye	A dye that, under suitable conditions, is capable of reacting chemically with a substrate to form a covalent dye-substrate linkage.
Relaxer	A wet process which releases the strains and stresses in fabrics.
Responsible Care	An international chemical industry initiative, requiring companies to demonstrate their commitment to improve all aspects of performance which relate to protection of health, safety and the environment.
Singeing	Cloth is passed across an open gas flame at a high speed to burn off the loose surface fibres.
Substantivity	The attraction, under the precise conditions of test, between a substrate and a dye (or other substance) where the latter is selectively extracted from the applicable medium by the substrate.
Surfactants	Dispersing agents, emulsifiers, detergents and wetting agents.
Synthetic fibre	Man-made staple fibres or filaments produced from polymers derived from chemical elements or compounds as opposed to those made by man from naturally occurring fibre-forming polymers.
Textile	Any item manufactured from natural or man-made fibres or filaments, e.g. yarns, threads, cords, ropes, braids, lace, embroidery, nets and fabrics made by weaving, knitting, braiding, felting, bonding and tufting.
Vat dye	A type of insoluble dye applied from a liquor containing alkali and a powerful reducing agent, generally hydrosulphite. The dye then becomes soluble and completely permeates cotton fibre. It is then oxidized and again becomes insoluble, thus becoming fixed to the fibre.
Viscose	A solution obtained by dissolving cellulose xanthate in a dilute solution of caustic soda.
Viscose fibre	The generic name for fibres formed by the regeneration of cellulose from viscose by treatment with a solution of electrolytes (salts and acids).
Warp	Threads running lengthways in a fabric as woven.
Water Pinch	To minimize the quantity of water used by introducing recycle loops and reuse cascades.

1 Introduction:

According to the United Nations Industrial Development Organisation (UNIDO) (2004, p 102) industrial pollution is becoming highly concentrated, with rising pollution intensity, especially around growing urban areas. This is owing to a number of complex factors such as the age of the technologies used, industrial practices employed, and other characteristics of industrial establishments in Sub-Saharan Africa such as size, ownership and embedded skills. The Hammarsdale industrial estate, shown in *Appendix A*, is situated midway between Durban and Pietermaritzburg in KwaZulu-Natal, South Africa. Among the industries operating there are seven textile mills and a chicken abattoir. It has been reported by Buckley et al. (1996, p 1.6) that the Hammarsdale Wastewater Works (HWW) receives approximately 65% of its flow by volume from those textile mills. Of the balance, 25% is from the chicken abattoir and 10% from domestic sources. The volume from domestic sources will increase significantly when a water-borne sewage system is installed in the residential township of Mpumalanga in order to improve sanitation and this will increase the load on the HWW. All of the industrial effluent is reticulated voluntarily to the HWW which was commissioned by the Department of Water Affairs and Forestry (DWAF) in 1981 and was owned and operated by Umgeni Water (UW) from 1983 to 2003. It is currently owned by the eThekwini Municipality (eTM) and operated by Ethekwini Water and Sanitation (EWS) and consists of 6 x 5 stage Bardenpho extended aeration activated sludge reactors designed for nutrient (nitrogen and phosphorus) removal. There is no installed anaerobic sludge digestion facility at the HWW. The treated effluent is discharged into the Sterkspruit River which flows into the Shongweni impoundment within the Mlazi River catchment area. This area is one of ten tertiary catchments within the jurisdiction of the proposed (June 2004) Mvoti to Mzimkulu Catchment Management Agency.

1.1 The concept of a trade tariff formula:

According to Barclay (2004, p 15) the textile industry is by nature a high water and energy user generating large volumes of effluent with a high chemical load. After several meetings between UW and representatives of the Hammarsdale industries including the Industrial Conservancy Association and Waste Minimisation Club a waste load based tariff equation was introduced on July 2000 as a financial incentive for industries to minimise, recycle and pre-treat their effluent before discharging it to the HWW. At present the cost to these industries of treating this effluent is calculated using a trade tariff formula (TTF) administered by EWS. According to Kerdachi (2002, p.iv) the underlying principle of a TTF is that industry and other users of the municipal sewerage and treatment system must pay for the services rendered by the local authority. When discharges of industrial effluent are made into a municipal sewer and conveyed to the treatment works for purification the local authority becomes the direct polluter of the receiving water. Taviv et al. (1999, p 2.2) points out that the theory behind polluters paying pollution charges is that they must pay for the costs incurred as a result of their pollution. However, if polluters were to pay the full costs of their pollution, the impact would be severe enough to cripple many economies. The aim is thus to reach an optimal level of pollution. In practice, charges are generally levied to induce polluters to modify their behaviour (deterrent objective) and to generate revenue to cover some of the polluter's externalities (revenue objective). In this regard, Kerdachi (2002, p iv) states that industrial effluent tariffs in South Africa are characterised by a wide variety of formulae that have been designed illogically and have no sound financial or technical basis.

1.2 Problem statement:

In principle the discharge of effluent in Hammarsdale is governed as follows;

- in the case of the industries, by Sewage Disposal Bylaws (SDBs) set by EWS, and
- in the case of EWS by a licence issued by the DWAF in terms of the National Water Act 36 of 1998 (NWA) which is regarded as *command-and-control* (CAC) legislation. This Act describes a General Effluent Standard (GES), detailed in *Appendix B* which specifies the quantity, quality and temperature of treated effluent which may enter a defined water resource such as the Sterkspruit River.

The HWW is currently not licensed by DWAF and operates temporarily in accordance with Exemption Permit 2131B issued to UW prior to 2003. It is thus incumbent upon EWS to obtain a licence from DWAF in order to comply with the requirements of the NWA and be allowed to operate the HWW on a permanent basis. However, because of design limitations, the HWW cannot remove the visible colour continuously and reliably from incoming raw textile effluent and point discharge colour pollution occurs. According to Umgeni Water (2003, p 6) the consequence of this is that the colour concentration of the water in the Sterkspruit River for the period from October 2001 to September 2002 was found to peak at 169^{o} Hazen units with a 95 percentile value of 121^{o} Hazen units and a median value of 84^{o} Hazen units. In terms of the NWA this situation is illegal and must be remedied.

According to UW, the overall compliance of the HWW with the GES for all determinands, especially colour, conductivity and total dissolved solids during the 2002/3 operating year is illustrated in *Appendix C*. The approach adopted by EWS has been to amend the SDBs to oblige the textile mills (by the use of permits), by certain dates, to remove all or most of the colour (to specified levels according to the test method used) from their effluent before it will be admitted to the HWW for disposal. Failure to comply with these colour standards will place the Hammarsdale textile mills in breach of the SDBs administered by EWS. This could result in the refusal by EWS to allow further quantities of raw textile effluent to be accepted for treatment at the HWW. Should this happen, the textile mills would have to cease production because there is no alternative means of disposing legally of the large volumes produced. The cost of compliance must be borne by the individual textile mills and this is cause for concern to them. In this regard Taviv et al. (1999, p 2.3) has pointed out that the most important considerations facing the use of economic measures to manage environmental costs are the possible negative repercussions such as increased production costs that they may have. In mitigation of this situation, compliance with the SDBs will qualify the textile mills for the implementation by EWS of a more lenient TTF which, together with savings in respect of water recovered for reuse, will offset the costs of such compliance.

1.3 Objectives:

Barclay (1996, p 1.1) states that water insoluble dyes such as disperse or vat have good exhaustion properties and the residual properties can be removed by physical methods such as flocculation or through adsorption. When textile effluent is discharged to a sewage works, colour due to these dyes is removed in the primary settling stages, with the water soluble dyes passing to biological treatment (conventionally aerobic processes). Of these dyes, reactive dyes are the most problematic as they are not easily adsorbed onto the biomass and, on average, 90% of reactive dyes entering a sewage works will pass through unchanged and be discharged to the receiving river. In this regard UW (2000, p 12) reported that colour and Chemical Oxygen Demand (COD) could be decreased by 80% and 50% respectively using pre-treatment of the textile effluent before it is reticulated to the a sewage works such as the HWW. This pre-treatment would comprise flow equalisation and cooling, adjustment of the pH to 5, flocculation of the colour with ferric chloride and polyacrylamide, settling to remove the flocculated matter and adjustment of the pH back to 7.

As a consequence thereof this dissertation aims to achieve the following objectives:

- To validate the technical merit of that UW report by undertaking a trial using a pilot-plant and advanced adsorption and flocculation technology to treat raw textile effluent on an end-of-pipe (EOP) basis.
- To assess the commercial ramifications of such treatment especially in terms of reducing TTF charges.
- To establish whether such treatment will enable the textile mills in Hammarsdale to comply with the permit requirements set by EWS.
- To consider other options open to the textile mills of avoiding having an effluent colour problem.

This dissertation is presented in the form of a *business case study* and details the results obtained from an EOP pilot-plant trial conducted at Textile Mill A (TMA) in Hammarsdale. Technical and economic issues are addressed and reference is made to related social and environmental matters.

1.4 Textile Mill A:

At the request of the management of TMA, the full name of the company will not be mentioned in this dissertation. TMA is a well established, ISO 9002 and 14001 accredited, NOSA 4-star Graded, *Responsible Care* signatory company manufacturing high quality, technologically excellent, high value speciality textile fabrics for both domestic and export markets. It is part of an international group which is represented in 31 countries and employs 14 000 people. This group, which is listed on the Frankfurt Stock Exchange, currently has an annual turnover in excess of US$ 1 billion. Further information relating to the business philosophy of TMA, the range of end products made from fabric manufactured by TMS, and the awards received by TMA appear in *Appendix D.*

At TMA, fibres such as acetate, cotton, Kermel®, Kevlar®, nylon, polyester and viscose are woven into fabrics which are dyed and finished on site. Different classes of dyes are used for different fibres and fabrics and each class requires a specific dyeing procedure. *Table 1.1* illustrates that reactive dyes form the largest component of the effluent dye mass in the raw effluent. As such it forms only 230 parts per billion of the total effluent flow rate of 15 700 kl per month. By comparison, there are between 6 and 13 parts per billion of gold (as gold chloride) in seawater. Apart from these dyes, the effluent produced by TMA contains low concentrations of surfactants and dyeing auxiliaries.

Table 1.1: **The classes of dyes and the approximate fractions thereof used monthly by TMA.**

Dye class	Mass purchased (kg)	Fraction exhausted (%)	Mass in effluent (kg)
Reactive	12	70	3.6
Disperse	60	96	2.4
Acid	26	96	1.0
Direct	1	50	0.5
Basic	1	96	0.0

1.5 The problem posed by effluent colour removal:

TMA uses reactive dyes on woven fabrics containing cotton and viscose fibres to achieve market approval related to fashion trends and consumer preferences. According to TMA, more cotton and less synthetic fibre is being processed in that vein.

Barclay (1996, p 3) describes the effluent related problem caused by reactive dyes as follows:

> *Reactive dyes have been identified as being the most problematical dye class with respect to treatment as they are water soluble and have relatively low exhaustion rates and are therefore present in high concentrations in the effluent. Due to their solubility they are not readily adsorbed onto floc or to biomass and hence do not report to the aerobic section at a wastewater treatment works* [such as the HWW].

This is corroborated by Gilfillan (1997, p 3.11) who wrote that:

> *Dyes have a high degree of chemical and photolytic stability in order to fulfil the fastness requirements of both retailers and consumers. As a result of this stability, it is difficult to degrade dyes under the aerobic conditions prevailing in biological plants at wastewater treatment works. Unless colour is removed by chemical or physical means, it may well pass through to the receiving water.*

Because of this reactive dye water solubility, the effluent produced by TMA is particularly problematic for the HWW which does not have either the chemical or physical means of removal mentioned by Gilfillan. The colour standards set by EWS for the TMA effluent are:

- For the Hazen method, 600^{o} H maximum (with a red transmittance of not less than 80%), or

- For the American Dye Manufacturers’ Institute (ADMI) method, 450 ADMI units maximum

This effluent is characterised from historical data supplied by EWS in *Appendix E* where the mean measured colour results are:

- 1 189^{o} H for the Hazen method, and
- 1 235 ADMI units for the ADMI method

For comparison purposes, *Table 1.2* shows the approximate colour contributions, measured in ADMI units, to the HWW from the Hammarsdale industries. Note that the contribution of the poultry abattoir consists principally of blood and does not contain inorganic textile effluent. This blood is soon to be removed from this poultry effluent as part of a protein recovery exercise.

Table 1.2: **Approximate volumetric colour contributions to the HWW measured in degrees Hazen units.**

Industry	**Contribution from all sources %**	**Contribution from textile sources %**
Textile Mill A	10	14
Textile Mill B	23	33
Textile Mill C	20	29
Textile Mill D	5	9
Textile Mill E	5	9
Textile Mill F	2	3
Textile Mill G	2	3
Poultry abattoir	33	-
Total	**100**	**100**

Source: Umgeni Water (2003, p 15)

From the foregoing it is apparent that each of the textile mills in Hammarsdale needs to address the problem of removing colour from its raw effluent. It is also apparent that TMA is not the principal contributor to the total effluent colour load. Should the recommendation recorded in this business study be used by TMA, it is possible that several of those textile mills, especially those using azo-reactive dyes, will follow suit to reduce the economic impact of effluent colour removal on their operations. In an era of increasing globalisation of trade, it is essential for the textile industry to be cognisant of ecological considerations and to project a *green,* or *eco-compliant* image so as to gain acceptance from international buyers and their customers. Congruent with the profit motive which drives business is the concept of *sustainable development* which was described in the Bruntland report in 1987 and is mentioned by Buckley (2004, p 3) as being;

> *… development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.*

In the same document Buckley refers to *sustainable development* as being;

> *…a way of improving the quality of life for people alive now and also for future generations*.

It must be emphasised that this dissertation is submitted as a partial fulfilment of the requirements for a specialist Masters degree in Business Administration and its technical content should therefore be differentiated from the requirements of a Masters degree in either Chemistry or Chemical Engineering.

1.6 The need for water resource management and sustainable development:

Cosgrove and Rijksberman (2000, p 6) have stated that a key characteristic of the world's fresh water resources is their uneven distribution in time and space. Indeed, according to Owen (2000, p 246) South Africa is the 26th most stressed in terms of water availability per person because it is a semi arid country with unevenly distributed rainfall (43% of the rains fall on 13% of the land) and with high annual variability and unpredictability. According to the United Nations Environmental Programme (UNEP, 2004 p 1) work done by the Swedish International Development Cooperation Agency (SIDA) has indicated that:

> *… the potential risks associated with water scarcity have become an emerging risk of strategic importance in businesses and their financial backers around the world. This is becoming even more important with rapid globalization within the business supply chain. Therefore, a business case for strategically addressing water challenges is getting stronger. While each organization must relate to water in its own capacity, the business case for the financial sector will come from acknowledging the potential risks associated with water scarcity and its potential effects on how they do business, thus encouraging them to seek innovative solutions for mitigating these tasks.*

In June 1992 the United Nations Conference on Environment and Development (the Earth Summit) was held in Rio de Janeiro, Brazil. From it came Agenda 21, a blueprint for sustainable development. It is reported by Umgeni Water, (2002, p 16) that the general objective with regard to fresh water management identified in Agenda 21:

> *… is to make certain that adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems and adapting human activities within the capacity limits of nature and combating vectors of water-related disease.*

Since 1992 there has been a groundswell internationally towards the implementation of the content of Agenda 21. Indeed, the United Nations World Summit on Sustainable Development which was held in Johannesburg during August 2002 reaffirmed its principles.

Indicative of the attitude of the South African government towards fresh water management is the preamble to the National Water Act 36 of 1998 (NWA, p 2.160.3) which recognizes that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users.

The interpretation and fundamental principles of the NWA (1998, p 2.160.12) state that:

> *Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognize the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act. National Government, acting through the Minister, is responsible for the achievement of these fundamental principles in accordance with the Constitutional mandate for water reform. Being empowered to act on behalf of the nation, the Minister has the ultimate responsibility to fulfill certain obligations relating to the use, allocation and protection of and access to water resources.*

In terms of the NWA the Minister of Water affairs and Forestry is required to establish a National Water Resource Strategy as well as Catchment Strategies in all of the 19 Water Management Areas within South Africa thereby providing the framework for the management of water resources for the country as a whole. This is congruent with the ideals of *sustainable development* espoused in Agenda 21.

The NWA (1998, p 2-160.22) defines 11 *water uses*, one of which is discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit. All such *water uses* must be either licensed by the Department of Water Affairs (DWAF) or subject to a General Authorisation condoned by the Minister. It is a criminal offence in terms of the NWA (1998, p 2.160.69) to unlawfully and intentionally or negligently commit any act or omission which pollutes or is likely to pollute a water resource.

The NWA has been described by Schreiner, (2004, cited in Africa Water Update, p 4) as being one of the most far-reaching and progressive pieces of water legislation in the world – balanced as it is on the three legs of sustainability, equity and efficiency.

In terms of water resource management and sustainable development it is incumbent upon TMA and the other textile mills in Hammarsdale to employ chemical or physical means to remove the colour from their raw effluent before it is reticulated to the HWW.

1.7 The structure of this dissertation:

The literature pertaining to the colour pollution of natural watercourses is reviewed in **Chapter 2**. Thereafter **Chapter 3** deals with the research methodology employed and describes the trading environment in which TMA operates, the technical options available to remove effluent colour, recommendations in respect of TMA made by Gilfillan (1997, p 6.28), and the dilemma faced by TMA regarding cost control. At the request of TMA a vendor was approached to conduct a pilot-plant scale EOP effluent treatment trial. **Chapter 4** provides details of the findings made and describes the results of this trial. **Chapter 5** describes the projected economic impact on TMA of a Build, Own, Operate and Transfer (BOOT) EOP effluent treatment plant and quantifies the relevant costs and savings. **Chapter 6** recommends and substantiates the use of such an EOP plant.

2 Literature review:

Library books, literature loaned from academics and industrialists, and relevant articles found on the Internet were read in order to gain insight into the problem posed by the disposal of raw textile effluent and how it is managed by both industrialists and legislators. From the literature consulted it is obvious that colour removal from textile effluents is a universal ecological problem involving costs in terms of the *polluter pays* philosophy. Regarding South African legislation, the GES published by DWAF shown in *Appendix B* stipulates that wastewater or effluent shall not contain any substance in a concentration capable of producing any odour, colour or taste. Whereas there is no General Quality Limit for colour in the Sewage Disposal Bylaws published by EWS, the permitting system described in section 2.8 thereof is intended to address any specific pollution problem.

This chapter provides a review of the most notable subject matter read.

2.1 The environment and development:

UNIDO (2003, p 5) provides a description of the Environmental Kuznets Curve illustrated in *Figure 2.1*.

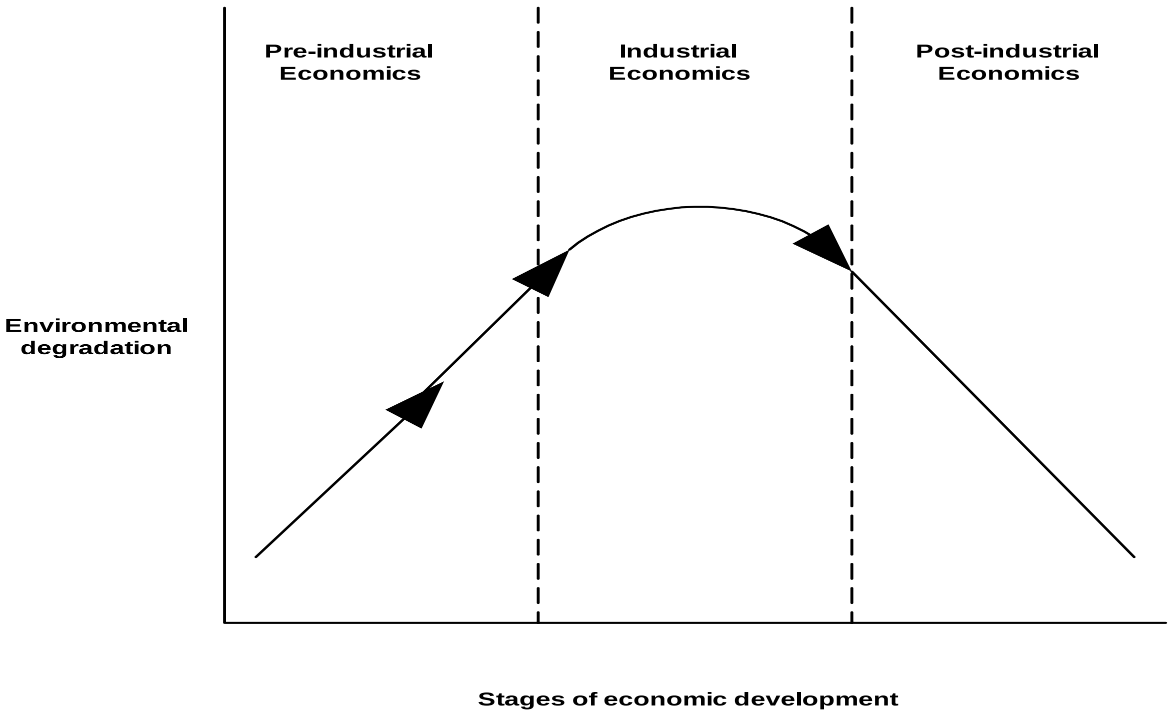


Figure 2.1: **The Environmental Kuznets Curve: a development-environment relationship.**

The theory behind this curve postulates that at low levels of development, as agriculture and resource extraction intensify and industrialisation increases, the emission and concentration of pollutants accelerates; at higher levels of development, structural change towards a rising share of services, lighter and cleaner industries and more efficient technologies as well as increased demand for environmental quality result in a leveling off and a steady decline in pollution levels. Considering this curve, it is desirable for industry in South Africa to make the transition from the industrial economics sector into that of post-industrial economics in order to reduce the amount of environmental degradation caused. To do this conscious policy is needed to reduce pollution and foreign assistance in clean technology transfer from developed countries can play a significant role.

2.2 Historical perspective:

The Water Research Commission (WRC) Project no. 78 (1987, p v) states that legislation in regard to the limited water resources of South Africa is constantly being reviewed by the authorities concerned and it will become increasingly difficult to discharge industrial effluents that are not treated adequately. In this regard, DWAF (2002, p 5) reports that, as society in South Africa developed, water quality management evolved. This evolution is outlined below:

- Up to the early 1950s the focus was on sewage disposal. The Public Health Act 36 of 1919 prevented sewage effluent from being disposed of into watercourses.
- Thereafter, during the 1950s, the nature of pollution changed because of increasing discharges from mines and industry. The Water Act 54 of 1956 was promulgated to control the industrial use of water and the treatment and disposal of industrial effluent. This Act required that all effluent be treated and returned to the body of water from which it was abstracted. As mining and industry and their resultant impacts increased, the Water Amendment Act 96 of 1984 provided for *Uniform Effluent Standards* such as the *General and Special Standards*, and *Special Standards for Phosphate*, to control pollution.
- During the 1980s and 1990s it became necessary to manage the cumulative impacts of the mining and industrial sectors on water resources. The approach changed to one that focused on the quality of the water body that received the waste and on the

requirements of all users. This is referred to as the Receiving Water Quality Objectives Approach.

- Currently, with the promulgation of the National Water Act 36 of 1998 (NWA) the focus is on an integrated resource, remediation and source-directed approach, which manages the water resource system as a whole. The NWA is based on the principles of sustainability, efficiency and equity meaning that protection of water resources must be balanced with their development and use. Congruent with this approach is that DWAF monitors water quality on an ongoing basis, for both surface and groundwater. Intensive local monitoring is conducted by the Regional Offices as well as national monitoring by the Institute for Water Quality Studies, and the Directorates Hydrology and Geohydrology. In addition, the National *River Health Programme* provides biomonitoring data which can be used by water resource managers to effectively manage the health of rivers. This monitoring has two legs. The first monitors the compliance of individual water users with their licence conditions and the second monitors the actual quality of the water resource itself and compares it to the relevant resource quality objectives. Corrective measures are then taken, including prosecutions where necessary. DWAF uses two major information systems in order to assess water quality performance and to provide information for management and decision-making. These systems are the Water Use Authorisation and Registration Management System (WARMS) which shows where, how and by whom water is used, and the Water Management System (WMS) which contains information on monitoring sites as well as information on stakeholders and institutional arrangements. The NWA requires that water quality be managed in an integrated manner at national level in terms of the National Water Resource Strategy, and at regional or catchment level in terms of the Catchment Management Strategy. Catchment Management Agencies (CMAs), which are statutory bodies, will be established by Government Notice with jurisdiction in defined water management areas. A CMA manages water resources and co-ordinates the water-related activities of water users and other water management areas within the water management area. When they are fully functional, CMAs are bound to play a large part in the practical development of water management practices.
- During 2003 the Environmental Conservation Act Amendment Bill was published. This Bill seeks to amend the Environmental Conservation Act 73 of 1989 by imposing compulsory charging, deposit systems and levies on specified waste streams

and by regulating certain activities and control products that may, or are likely to have significant detrimental effects on the environment or human health when introduced into waste streams.

- During 2004 the National Environmental Management Biodiversity Act was promulgated to provide for the protection of ecosystems that are threatened or are in need of protection to ensure maintenance of their ecological integrity.

2.3 The concept of Industrial Ecology:

Allied with the concept of *sustainable development* is the concept of *industrial ecology* which recognizes that the capitalistic and profit driven nature of industry should not be allowed to damage surrounding ecosystems. Buckley and Barclay (2003, p 8) described this concept as the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural and technical evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total material cycle from virgin material, to finished material, to component, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy and capital.

2.4 The problem of colour in textile effluents:

Specific to the textile industry and textile effluents, Cooper (1995, p 1) states that the environmental issues associated with residual colour in treated textile effluents are not new, and that for the last decade or so a number of direct dischargers, both sewage treatment works and commercial textile operations, have had to perform to colour requirements placed on the treated textile effluent discharge, which have been progressively and perceptively tightened. Buckley and Barclay (2002, p 1.1) describe dyehouse effluents as being complex in nature, consisting of concentrated waste process water containing a wide and varied range of dyes and other products, rinsing and cooling water. In general, these effluents are highly coloured, high in biological oxygen demand (BOD) and chemical oxygen demand (COD), have a high conductivity and are alkaline in nature. They add that:

> *The effluent is ranked second highest with respect to hazardous waste intensity and principally affects water quality.*

This complex character of dyehouse effluent is also described by Carliell (1993, p i) and by the Direct Estimation of Ecological Effect Potential (DEEEP) being developed by DWAF (2003, p 3).

2.5 The role of management in improving environmental performance:

Formalized Environmental Management Systems (EMS) were described by Hillary (1997, p 1) and include the first EMS standard, BS 7750 (1992) which was published by the British Standards Institute (BSI), and ISO 14001 developed by the International Organization for Standardization (ISO). Hillary stressed that differing environmental regulations can be trade barriers, especially for developing countries, but it is necessary to identify to what extent the differing voluntary standards restrict trade.

Barclay and Buckley (2002, p 3.1) added that, because all organisational activities, products and services will interact with the environment, an effective EMS is needed to deal with this complexity. This EMS must therefore be interwoven with the overall management of the company. The importance of an EMS is that it manages, measures and improves environmental performance and leads to efficient compliance with environmental requirements.

An Internet reference to EMS is provided by the European Integrated Pollution Prevention and Control Bureau (the IPPC) whose task is to catalyse an exchange of technical information among industries in order to improve their environmental performance. In terms of IPPC directive 96/61/EC reference documents designated as BREFS must be taken into account when the competent authorities of European Union (EU) Member States determine conditions for IPPC permits.

Duncan (1997, p 157) describes a growing number of EMSs which are enforced by agents of government and apply nationally and internationally. One of these is the European Union Eco-Management and Audit Scheme (EMAS) which was introduced into a number of states in the EU by way of a European Commission regulation. He also alludes to less formal systems typified by the British Chemical Industries Association *Responsible Care* programme which advocates an organizational commitment to continual improvement. Other systems for environmental reporting are promoted by industrial groups such as the World Industry Council for the Environment and the Public Environment Reporting Initiative. In South Africa, DWAF (1999, p 11) stresses the need for water demand management and proposes the following definition thereof:

The adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

2.6 International support for improving environmental performance via Cleaner Production:

There is abundant support internationally for this theme. BS 7750, EMAS, the EU Ecolabel Award Scheme (EUEAS) and the ISO 14000 series are evidence of this. The move towards Cleaner Production (CP) is gaining momentum and Buckley (2004, p 4) reports that the United Nations Environmental Programme (UNEP) provides a complete definition and explanation of cleaner production. Indeed, UNEP defines CP as being:

…the continuous application of an integrated preventive environment strategy to processes, products and services to increase overall efficiency, and reduce risks to humans and the environment. CP can be applied to the processes used in any industry, to products themselves and to various services provided in society.)

According to Sybren de Hoo (1997, p 56) the first step in the transition to a CP economy is a shared vision and consensus and the establishment of the right climate for financial and technical assistance from both national and foreign institutions. She mentions that the Organisation for Economic Co-operation and Development (OECD) countries are themselves still experimenting with appropriate strategies and policies. UNIDO (2004, p 98) reports that there is no question that policy, industrial practices and technology are significant determinants of pollution levels, along with the scale of production and the composition of output. A distinction needs to be drawn between production technology and pollution-abatement technology. CP technology yields double dividends because it saves on resource inputs and also reduces waste. Pollution-abatement technology is supplementary in that it deals with residual pollution and accumulated pollution from the past.

2.7 The evolution of Cleaner Production:

Buckley (2004, p 8) reports that there is increasing pressure on industries to reduce their environmental footprint. This pressure is expected from a number of directions including regulators, customers, end users, neighbours and civil society. The application of CP techniques is in line with the trend to *triple bottom line* accounting (people, profit, planet) and *sustainability* reporting. There is a range of techniques that is useful in the short, medium and long term. For an industry [for example a textile manufacturer such as TMA] that is active in the export market it is essential to start to implement CP techniques in order to be allowed to enter the market, never mind being a preferred supplier.

Gilfillan (1997, p 1.3) draws a distinction between CP and similar terms. She states that:

> *Many similar terms are often interchanged with CP, including waste minimization, pollution prevention and source reduction. CP should not be confused with pollution control. Pollution control deals with wastes that are produced, whereas cleaner production focuses on the cause of waste.*

Buckley (2004, p 8) concurs with this distinction drawn by Gilfillan and lists the steps in the evolution of CP as being:

- Dilute and disperse
- End-of-pipe treatment
- Pollution prevention/ waste minimization
- Cleaner production
- Cleaner production **of goods and services**
- Cleaner production **and consumption**

Buckley (2004, p 9) states that CP does not deny growth, growth must be ecologically sustainable. He stresses that CP is a *win-win* strategy because it protects the environment, the consumer and the worker. It should also improve industrial efficiency, profitability and competitiveness. According to DANIDA (2003, p 4) the major difference between CP and pollution control is one of timing. Whereas pollution control is a reactive action, CP is pro-active. DANIDA adds that:

> *This is not to claim that 'end-of-pipe' technologies will never be required. In practice there will always be some residue of some sort from many processes and obsolete products. The new approach is to tackle problems using a Cleaner Production concept, which will lead to a reduced need for end-of-pipe technologies and may in some cases even eliminate the need for them completely.*

DANIDA (2003, p 3) alludes to the concept of a *waste management hierarchy* and describes four characteristic ways in which industrialized nations have responded to pollution and the environment. They are:

- Firstly, by ignoring the problem

- Secondly, by dispersing and diluting the pollution so that its effects are less harmful or apparent.
- Thirdly, by trying to control the pollution and the wastes (the so-called EOP or pollution control approach).
- Fourthly, by CP through the prevention of pollution and waste generation at the source of production.

DANIDA (2003, p 4) States that a key element of this new approach is the implementation of the waste management hierarchy.

Figure 2.2 illustrates this waste management hierarchy in the form of an inverted triangle.

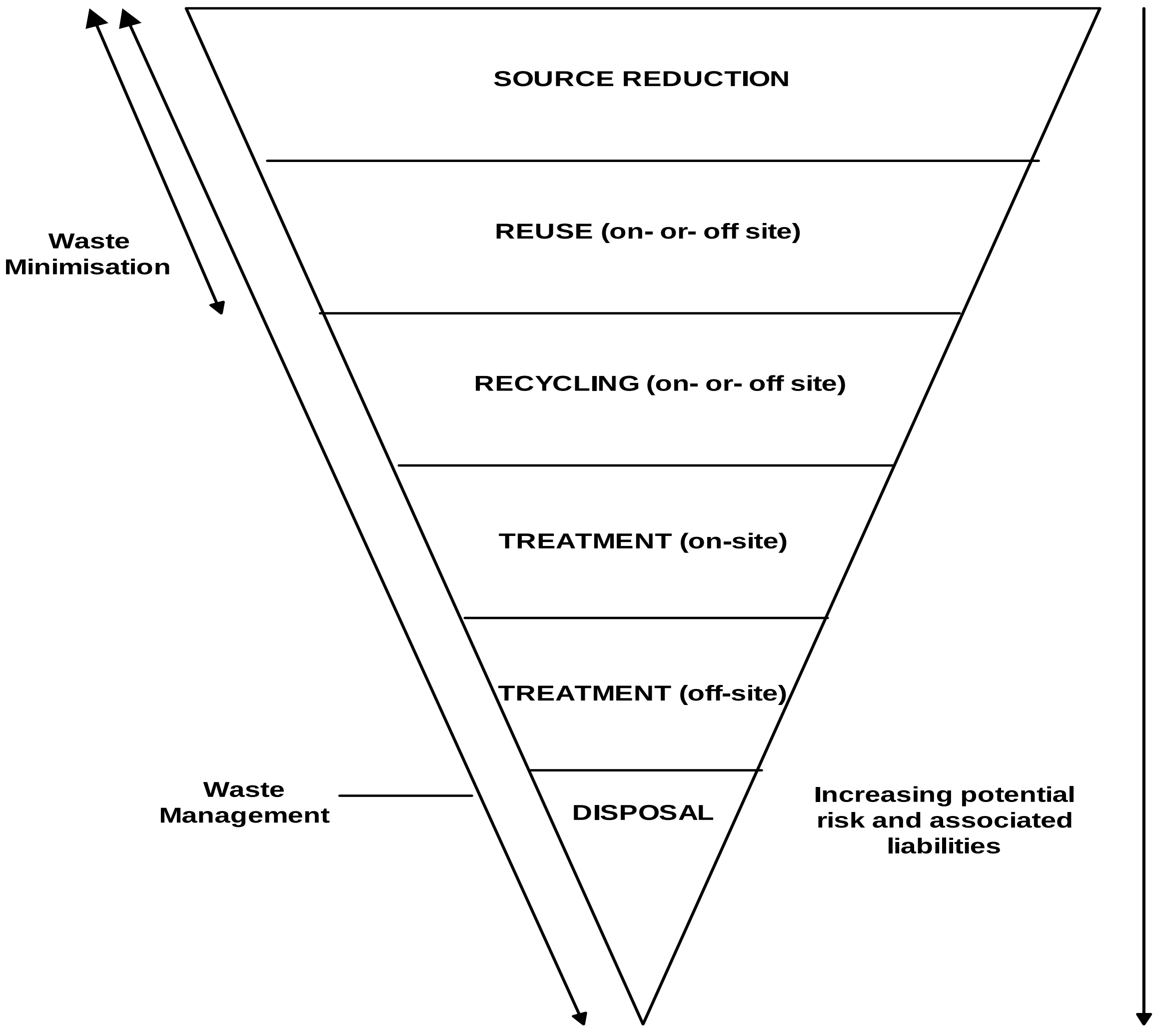


Figure 2.2: **The waste management hierarchy.**

2.8 The tools of Cleaner Production:

Buckley (2004, p 6) categorises these into non-technological and technological tools.

2.8.1 The non-technological tools.

These include:

- A regulatory approach which, in contrast to the CAC legislation encourages a more co-operative climate between the regulators and the regulated in setting and enforcing standards. A shared responsibility between government and industry should enhance the likelihood of a more open exchange of information between the parties and allows greater flexibility regarding the means of meeting standards.
- Market-based instruments which seek to address the market failure of *environmental externalities* either by incorporating the external cost of an industry's polluting activities into that industry's private cost (for example through taxation) or by creating property rights and facilitating the establishment of a proxy market (for example by using tradable pollution permits).
- Using information, such as the disclosure of an industry's environmental performance to engender transparency regarding ecologically sensitive matters.

An important development has been the formation of the Clothing and Textile Environmental Linkage Centre (CTELC) funded by DANIDA and the Department of Trade and Industries (DTI). The aim of the CTELC is to strengthen the link between the clothing industry, retailers and CP in South Africa.

2.8.2 The technological tools.

These include:

- Waste minimisation which encourages participation by all employees and has fast and easily identified financial and environmental returns.
- Environmental life cycle assessments which include the extraction and processing of raw materials followed by manufacturing, distribution, use, maintenance, recycling and final disposal plus all the transportation involved. This tool permits the calculation of science-based environmental scores for different impacts which range from global impacts (such as ozone depletion) to regional impacts (such as acidification) to localized impacts (such as toxicity). These scores allow for comparison between different products, services or activities and they also allow the detection of the most *environmentally unfriendly* sections of their life cycle. Such scores can thus be used to detect problem areas in complex systems. They

can be seen as a focusing tool capable of highlighting areas where other tools (such as management systems) have to be deployed to achieve the most efficient environmental improvement.

- Process integration such as *thermal pinch, water pinch* and *combined water and material pinch* which realize efficiencies which would not be possible for individual processes.
- Green chemistry which promotes innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture and use of chemical products. One such system is the *score system* which allows for the identification of chemicals and dyestuffs which impact negatively on the environment so that remedial action can be taken. This system is included in the EU Best Available Techniques (B.A.T) documentation. It is based on a rating, from A to D, of those substances likely to have an impact on the environment of industrial effluents.

  A: Estimated amount of chemical or dyestuff that goes to drain.

  B: Biodegradability – how quickly the substance degrades in the environment.

  C: Bioaccumulation – how the substance accumulates in the environment.

  D: Toxicity – how harmful the substance is to living organisms in the environment.

Figure 2.3 provides a typical plot of exposure score vs. toxicity.

- De-materialisation which separates income streams from the mass of chemicals sold resulting in fewer molecules being sold at a greater profit. In this way the management, safety and disposal of a chemical is outsourced to specialists in their field of expertise.

All of these tools can be used in the pursuit of the water quality management goal which is defined by DWAF (2002, p iv) as being:

> *Achieving water quality that is 'fit for use' and maintaining aquatic ecosystem health on a sustainable basis by protecting the country's water resource, in a manner allowing justifiable, social and economic development.*

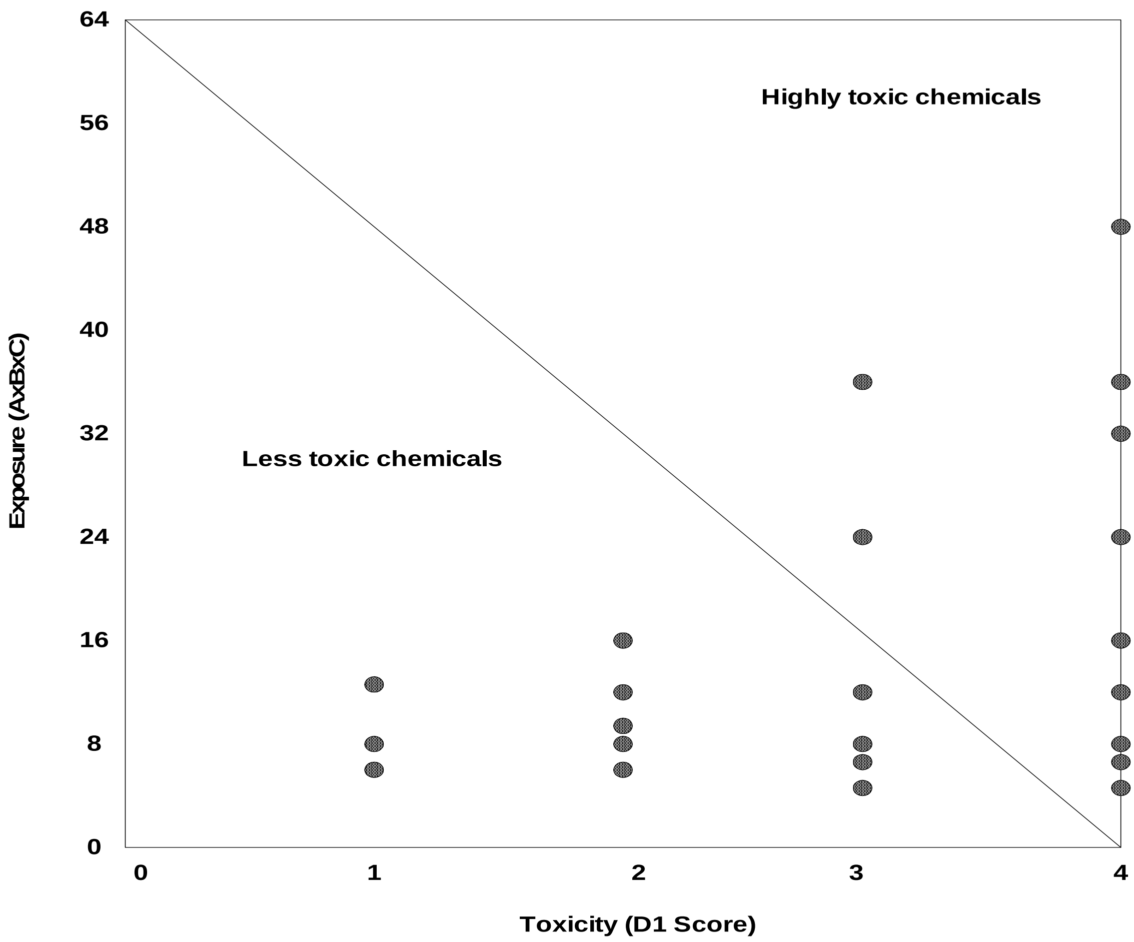


Figure 2.3: **A typical plot of exposure score vs. toxicity.**

Buckley and Barclay (2003, p 14) add that many case studies world-wide confirm that the implementation of CP reduces pollution and environmental risk. They stress the good business sense aspect of CP by listing the following advantages conferred by CP:

- More efficient use of raw materials.
- Less waste generated.
- Lower operating costs.
- Improved worker productivity.
- Reduced EOP treatment costs.
- Decreased health costs.
- Increased profits.

These advantages are confirmed by UNIDO (2004, p 100) which states that Environmentally Sound Technologies (ESTs) are less polluting, use resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies that they replace. ESTs are often divided into two categories;

treatment control technologies and preventive technologies. Treatment control technologies, traditionally called end-of-pipe (EOP) technologies have been used at the end of the production process to collect pollutants and then separate or neutralize them. Preventive technologies, often called cleaner technologies on the other hand, are manufacturing processes or product technologies that reduce pollutants or waste, and production inputs (raw materials, water and energy). They often reduce the need for more costly treatment and control technologies.

2.9 Relevant South African policy interventions regarding Cleaner Production:

According to DANIDA (2003, p 33) the following legislation is deemed to be of direct relevance to waste and wastage minimisation:

- The Constitution of the Republic of South Africa Act 108 of 1996.
- The National Environmental Management Act 107 of 1998.
- The Environmental Conservation Act 73 of 1989.
- The Occupational Health and Safety Act 101 of 1993.
- Regulations for Hazardous Chemical Substances (GN.R.1179 GG16596 of 1995) published in terms of *Occupational Health and Safety Act of 1993.*
- The National Water Act 36 of 1998.

Buckley (2004, p 3) describes relevant South African policy interventions as follows:

> *The concepts of sustainable development run through the recent South African strategy and legislation. The [South African] Constitution makes reference to a right to a …* ***clean and healthy environment*** *… In 1993 CP was introduced in a national environmental development plan which was formulated by the Department of Trade and Industries (DTI) and the Department of Environmental Affairs and Tourism (DEAT) in collaboration with the Danish government. The policies of these departments now reflect the emphasis on CP, which has been embraced in the NWA and the Water Services Act 108 of 1997 (WSA). The Department of Arts, Culture, Science and Technology (DACST) in 1995 undertook a technology foresight exercise as part of a plan to review and reform the science and technology system. The aim was to help to identify specific technologies and technology trends that would best improve the quality of life of all citizens over the next 10 to 20 years.*

Buckley (2004, p 3) refers to activities which took place during 1999 to promote CP. They involved the DTI, the DEAT and the Danish Cooperation for Environment and Development. Similar work since 2002 has involved the Danish International Development Assistance organization (DANIDA). At the World Summit on Sustainable Development in September 2002 the National Cleaner Production Centre was formed by an agreement between the DTI, The Council for Scientific and Industrial Research (CSIR), UNIDO and the donor countries of Austria and Switzerland. The WRC has also been funding research projects which support CP. South African legislation relevant to the ideals of CP and pollution liability include the WSA, The NWA, the National Environmental Management Bill of 1988 (NEMB) and the proposed Integration Pollution Control and Waste Management Bill.

2.10 An environmental co-operation contract:

UNIDO (2004, p 94) states that, due to a number of factors, the most notable being lack of access to technological resources, pollution from the textile sector is considerable worse in Sub-Saharan Africa than elsewhere on a per unit basis as many operations do not practice any sort of waste treatment at all. The Chamber Digest (2004, p 12) describes an environmental co-operation contract which was signed by EWS and the Norwegian Pollution Control Authority (NPCA) to establish, within a period of two years, an upgraded industrial permitting, auditing and Information Technology (IT) system in EWS, the final outcome of which is to achieve a reduction in industrial pollution which will be measured over time by the IT system. This contract should provide major benefits to EWS, industry and the communities who interface with such industries. This is a first in South Africa and, in line with other international co-operation projects involving EWS, the work will inform national strategies.

2.11 The commercial impact of the permitting system:

From the foregoing it is thus evident that effluent quality compliance is going to have a significant commercial impact on the established South African textile industry in respect of both domestic and international trade. The affairs of those textile mills seeking to develop export markets for their products need to withstand scrutiny in terms of environmental matters. Economic incentives and disincentives are bound to emerge as time goes by. Regarding such matters, Miller (2002, p 12) provides the following comment:

> *How can economic incentives be used to improve environmental quality and reduce resource wastes? Market forces can help improve environmental quality*

and reduce resource waste, mostly by encouraging internalization of external costs by using economic incentives (rewards) and economic disincentives (punishments). This is based on a fundamental principle of the marketplace in today's mixed economic systems. What we reward (mostly by government subsidies and tax breaks) we tend to get more of, and what we discourage (mostly by regulations and taxes) we get less of. An incentive is to use product or ecolabelling programmes to encourage companies to develop green products and services and to help consumers select the most environmentally sustainable products and services. A disincentive may use green taxes or effluent fees. In other words, to be politically acceptable environmental taxes must be seen to be tax shifting instead of a tax burden approach.

An economist's viewpoint is provided by Briscoe (1996, p 8) who states that it is relevant to focus on the issue of the *value* of wastewater treatment, or the *value* of environmental quality. The usual approach to this has been to assume that it is impossible to assess this *value* and, instead, to promulgate standards (by type of treatment required, quality of effluent stream, or quality of receiving stream). This is often perceived as a means of avoiding the issue of *value*. UNIDO (2004, p 94) points out that one of the main difficulties is that local authorities, in their quest to create jobs often perceive the adverse environmental and public health consequences as a necessary price to pay for economic development. Sometimes incentives are aligned in such a fashion that local authorities benefiting from the collection of water fees and wastewater charges are reluctant to enforce water-use reduction policies. There is also a widespread fear that correct pricing policies will drive companies away due to a perceived loss of competitiveness, with subsequent increases in unemployment. Ill considered subsidies accentuate the problem as there is no incentive to consider CP options which would have economic, public health and environmental benefits. Overall, it is clear that until the financial and economic benefits of environmentally sustainable business are made clear to all concerned, the misconception will persist. The incentive offered by EWS to TMA is to apply the more lenient EWS trade tariff formula instead of the UW trade tariff formula when TMA complies with the permit conditions set by EWS. *Appendix F* illustrates the differences between the EWS trade tariff formula and the UW counterpart. An added benefit would be the reuse of water recovered from treated effluent.

2.12 The attitude of the public to colour pollution in natural watercourses:

According to DANIDA (2004, p 8) one of the main concerns with respect to textile effluent is that of colour as it is a visible source of pollution and this often elicits highly emotive responses. Colour in rivers may also impact on aquatic life by preventing the penetration of light thus interfering with the natural photosynthesis process. Cooper (1995, p 29) describes the attitude of the UK public to colour pollution. He states that the presence of coloured effluents in watercourses is no longer acceptable. Since the focus on CP the general quality of rivers has improved, and the wildlife, conservation and recreational value are increasing. Bright, unnatural colours are a cause of complaint and the public are increasingly critical of industry polluting the environment. Colour standards are being developed for watercourses and being translated into limits for the control of discharges. The National Rivers Authority intends to achieve a progressive reduction in colour pollution over the next few years by introducing new limits for the discharges not already subject to control of colour.

The attitude of the South African public is no different to that in the UK. With sponsorship from the South African government, the colour pollution of natural watercourses must end.

2.13 Social and user considerations in the catchment below the Hammarsdale Wastewater Works.

The HWW discharges treated effluent into the Hammarsdale Dam situated on the Sterkspruit River. Downstream of this dam the Sterkspruit River flows over a 60 m high waterfall, through an uninhabited gorge and then into the Shongweni impoundment. According to UW (2003, p 6) this discharge causes an increase in the colour of the Sterkspruit River, in terms of the median colour concentration from 32^0 Hazen to 64^0 Hazen units. Umgeni Water (2003, p 7) also states that:

- The Sterkspruit River is not used as a source of potable water. The use of the Shongweni impoundment for large-scale water supply to the greater Durban area was discontinued in 1992. Communities living in proximity to the Sterkspruit River below the gorge use piped mains water supplied by EWS, natural springs or borehole water.
- Small sections of the Sterkspruit River continue to be used for bathing, fishing and swimming by small numbers of the local community. An important recreational use of the water derived from the Sterkspruit River system continues to be at the Shongweni impoundment where the Shongweni Resources Reserve (operated by Msinsi Holdings) is situated. This Reserve is focused on the integration of sustainable rural development and resource conservation and it is an important recreational area for the eThekwini

and Pietermaritzburg metropolitan areas in terms of fishing, hiking, horse trails and limited boating. Colour derived from the HWW has no effect on either the Shongweni impoundment or the operation of the Reserve.

- The Hammarsdale Dam, the Sterkspruit River and the Shongweni impoundment sustain a large variety of fish and bird life and other natural biota. The staff of Msinsi Holdings maintains extensive lists of flora and fauna in the Shongweni Resources Reserve if these are required. Biotic surveys have indicated good biotic diversity in the system. Whereas water hyacinth continues to grow it is managed and controlled effectively by UW as part of its environmental management and resource protection programme.
- Because of the nature of the terrain, the agricultural potential of the Sterkspruit River below the Hammarsdale Dam is very limited. Valley sides are steep with erodible sandy soils with very low humic and clay contents. Rainfall is markedly seasonal, and due to the very limited areas of gently sloping land and their distance and elevation from the river, irrigation is uneconomical and does not occur. Although pockets of alluvial deposits in the valley bottom may be utilizable for crop production on a sustainable basis, these are very limited. Grazing remains the best agricultural use of the area despite the already degraded nature of the soil and the bushveld.

The removal of colour from the Sterkspruit River is desirable in terms of the concept of environment protection and the equitable and sustainable use of water.

3. Research methodology:

Prior to 2000 there was no TTF applicable to raw effluent reticulated to the HWW by the Hammarsdale industries. Since 2000 the effluent treatment charges levied on TMA have been affordable to TMA. The management of TMA is however apprehensive about the potential cost increase and the impact on its profitability of the introduction of a revised effluent colour standard as a prerequisite to the granting of an effluent discharge permit by EWS and the introduction of the EWS trade tariff formula. TMA is concerned that the cost of removing colour from its raw effluent will render it uncompetitive. Regarding the nature of this problem, Thoresen (1997, p 203) states that:

> *A company must be able to cope with the opportunities, threats and uncertainties presented by external factors, and this is made possible by developing and using an integrated management system. It is essential that environmental issues, with impact on the business opportunities of the company, are treated at a strategic level.*

The following five sections are thus relevant:

- **Section 3.1** describes the trading environment in which TMA operates.
- **Section 3.2** describes the technical options available to TMA to remove effluent colour.
- **Section 3.3** describes the recommendations made by Gilfillan (1997).
- **Section 3.4** describes the categories of Environmentally Sound Technologies.
- **Section 3.5** emphasises the dilemma faced by TMA regarding cost control.

3.1 The trading environment in which Textile Mill A operates:

According to Buckley et al (1996, p 1.1):

> *Over the past 13 years, the South African Textile industry has been in a state of decline and with the lowering of textile tariff rates, the industry is going to be increasingly exposed to international competition over the coming years. Therefore, in order for the textile industry to survive it must become more export orientated and economically competitive. However, with the introduction of ecolabelling, it is becoming increasingly difficult to export to the European Union and the United States unless textiles are manufactured according to this environmental legislation. The South African textile industry must therefore work*

towards reducing their environmental impact and increasing their efficiency by pollution prevention.

A later description of the South African textile industry by Barclay and Buckley (2002, p 1.3) appears in *Appendix G*. The market for textile goods remains highly competitive. Consequently all producers of textile goods are obliged to seek competitive advantage in order to remain in business profitably. Thompson and Strickland (2003, p 150) stress the importance of a strategy for achieving such competitive advantage and state that:

> *A company's competitive strategy consists of the business approaches and initiatives it undertakes to attract customers and fulfill their expectations, to withstand competitive pressures, and to strengthen its market position.*

TMA describes itself as being a global producer of high technology industrial, technical and specialized fabrics which are engineered for performance and reliability. Kotler (2000, p 289) describes the concept of *Performance Quality* which may be applied to the products manufactured by TMA as conformance quality, durability, reliability, reparability and style. In terms of the five generic competitive strategies mentioned by Thompson and Strickland (2003, p 151) and adapted from the work of Porter (1980, p 35) the competitive strategy adopted by TMA is one of being a focused (or niche market) lower cost producer. TMA thus concentrates on a narrower buyer segment and attempts to out-compete rivals by offering niche members customized attributes that meet their tastes and requirements better than the rival's products. There are however risks involved with such a strategy and these include;

- the chance that rivals will find effective ways to match this focus in serving the target niche,
- the chance that the needs and preferences of the niche members will shift over time toward the product attributes desired by the majority of buyers i.e. entry barriers will be lowered, and
- the chance that the segment will become so attractive that competitors will be attracted thereby intensifying rivalry and splintering segment profits.

It is thus important for TMA to be flexible in terms of market vicissitudes and to be able to cater for rival marketing tactics. Given these circumstances, it is imperative that the cost of solving its effluent colour problem does not hamper the business of TMA nor does it compromise its ability to compete in international markets. A European Commission product fact sheet (Barclay and Buckley 2002, p 1) states that the textile and clothing industry is facing new challenges following the globalization of the world economy and the competition of fast-growing Asian markets. In order to stay in the business, companies have to look for differentiating factors by designing high value textiles and clothing. The European eco-label described in *Appendix H* is the only certificate of environmental quality issued by an independent organization and is valid throughout the EU, Norway, Liechtenstein and Iceland. Without it, market acceptance is very difficult to achieve. A further aspect of globalised trade is the influence of currency exchange rates. The growth and prosperity of South African textile producers such as TMA is dependant on export volumes, especially to the United States of America (the USA) in terms of the African Growth Opportunities Act (AGOA). AGOA is USA legislation which was signed into law on 18 May 2000 to liberalise significantly trade between the USA and 37 designated Sub-Saharan African countries. AGOA builds on existing USA trade programmes by expanding the duty-free benefits previously available only under the Generalised System of Preferences (GSP) programme. Export volumes to the USA are thus dependant on the ability of such articles to be priced competitively in the USA. It follows that, when the South African Rand (ZAR) is weak against the United States Dollar (US$) exports will be priced competitively.

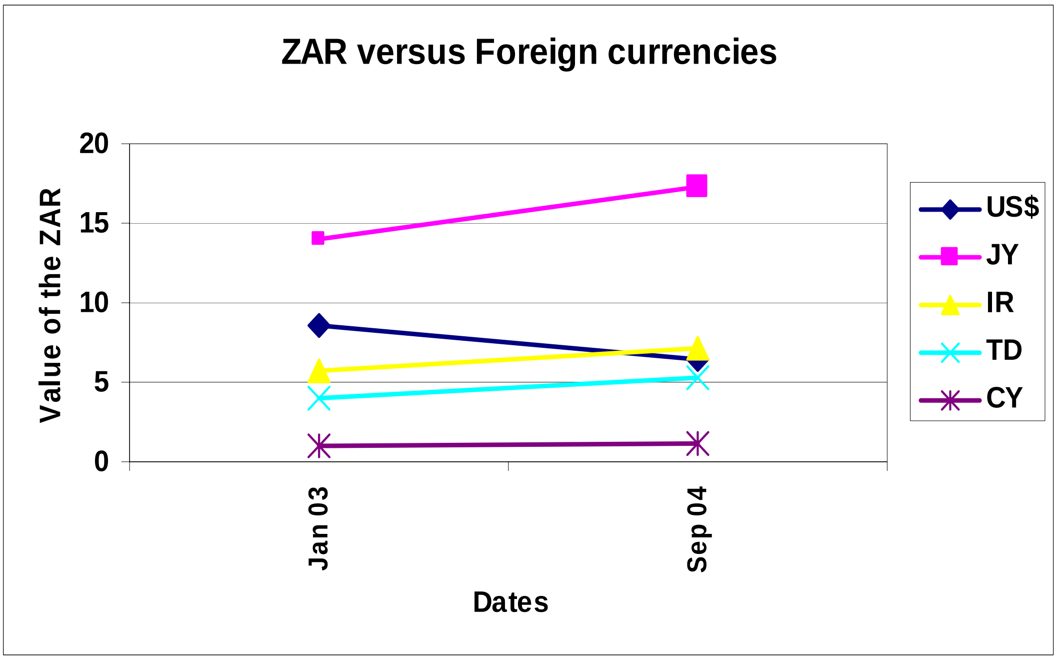


Figure 3.1: **The exchange value of the ZAR against several foreign currencies affecting the trading environment in which TMA operates.**

The converse is also true. Currently, the weakening of the US$ against the ZAR has affected export volumes to the USA adversely. Further, domestic market trading problems are created when inexpensive imports of textiles and textile products from the Far East enter the South African market. Consequently the South African textile industry is suffering financially because its exports to the USA have become less profitable, and competing imported products have become less expensive. It is reported by Bisseker (2004, p 9) that, during 2003 alone, seven South African textile mills closed down and 20 000 jobs were lost because of such poor trading conditions.

The net result is that a company such as TMA must seek a solution to the effluent colour removal that does not add significantly to its costs.

Information relevant to the South African textile industry as supplied by the South African Textile Federation appears in Tables 3.1 and 3.2. The currency exchange rates used in Table 3.1 appear in Table 3.2.

Table 3.1: **South African textile industry statistics summary 1999-2004**

	1999	**2000**	**2001**	**2002**	**2003**	**2004est**
Domestic sales (ZAR x 10^3)	9 774	10 164	10 470	13 412	12 458	12 500
% change year on year		4.0	3.0	28.1	-7.1	0.3
Imports (ZAR x 10^3)	4 023	4 656	5 192	6 929	5 883	5 812
% change year on year		15.7	11.5	33.5	-15.1	-1.2
(US$ x 10^3)	658	671	604	659	778	867
% change year on year		2.0	-10.0	9.1	18.1	11.4
Exports (ZAR x 10^3)	2 618	2 888	3 372	4 517	3 791	3 310
% change year on year		10.3	16.8	34.0	-16.1	-12.7
(US$ x 10^3)	428	416	392	430	501	494
% change year on year		-2.8	-5.8	9.7	16.5	-1.4
Contribution to GDP (%)	1.2	1.1	1.1	1.2	1.0	1.0
Textile consumption per capita in South Africa (in ZAR)	280	298	307	400	350	400
Inflation (%)	5.4	5.7	6.6	9.3	6.0	5.2
Utilisation of prod capacity (%)	84	80	81	82	75	
Spun yarn production (‘000 tons)	90	93	95	96	87	

Fabric production (mill m^2)	580	556	525	545	508	

Source: Textile Federation

Table 3.2: **Currency exchange rates.**

ZAR/foreign currency unit	1999	2000	2001	2002	2003	2004est
US$	6.11	6.94	88.60	10.52	7.65	6.73
% change year on year		13.4	24.0	22.2	-28.1	-11.0
UK₤	9.89	10.48	12.40	15.76	12.34	12.26
% change year on year		6.0	18.2	27.2	-21.7	-0.6
EU€	6.52	6.39	7.71	9.90	8.53	8.29
% change year on year		-2.0	20.5	28.5	-13.9	-2.8

Source: SA Reserve Bank

3.2 The technical options available to Textile Mill A to remove effluent colour:

The solution to TMA's effluent colour removal problem lies in combinations of technical options applied using integrated management principles. The most obvious solution will involve application of the principles of CP followed by the separation of any effluent containing reactive dyes from the main effluent stream. The decision made by TMA will be influenced by cost-effectiveness.

These options include:

3.2.1 <u>Using anaerobic digestion as an intervention to decolourise effluent containing reactive dyes.</u>

UW (2003, p 11) reported that, during June 2002, destructive technology (to break up chromophoric molecular groups) in the form of anaerobic decolourisation trials of the raw Hammarsdale textile industry effluent at the nearby (12 km) Mpumalanga Wastewater Works (MWW) was discussed with EWS. The MWW anaerobic sludge digesters were known to have spare capacity and UW proposed that low volume, highly concentrated dye-bath (*coloured*) effluent be transported by road tanker from the Hammarsdale textile mills to the MWW. At that time it was estimated by UW (2003, p 11) that the cost of sending such effluent at the rate of 14m^3 per week would be ZAR 156 000 per annum with no prospect of water recovery for reuse. In addition, it would have cost TMA the sum of ZAR 430 000 to separate the *coloured* from the *clean* effluent in their dyehouse. This methodology had been tested previously by the

University of Natal, Pollution Research Group, in the Pinetown-Umbilo area and had shown anaerobic treatment of azo-reactive dyes to be effective. Work done by Petlane (2002, p 51) confirmed that it is feasible to treat coloured effluent in an aerobic digestion treatment process to remove the colour provided that it is a two stage process combined with aerobic process to remove COD sufficiently.

3.2.2 Using Cleaner Production (CP) methods.

These methods include:

- improving the fixation of dyestuffs onto the fibres of the fabric by using multifunctional dyes,
- targeting the dark shades of exhausted reactive dyes for separation from the general effluent stream,
- investigating different dye chemistries, such as the replacement of water soluble dyes with those that are water insoluble,
- changing the chemical structure of certain dyes to give more biodegradable or bioaccumulated alternatives,
- reducing the quantity of clean water that is polluted,
- investigating equipment changes,
- reusing as much water as possible thereby reducing effluent volume,
- identifying the most cost-effective point in the discharge chain to remove pollution, and
- dyeing in non-aqueous systems such as supercritical fluids.

Barclay (2004, p 2) states that by implementing a programme of CP and by applying B.A.T. a number of benefits can be achieved all of which add up to financial savings of between 2 and 5% of the annual turnover of a textile mill. These benefits include;

- reduced risks to the environment,
- improved process control and efficiency,
- reduced raw material, water, energy and chemical inputs,
- reduced generation of waste, and
- competitive edge.

3.2.3 Using water minimisation techniques.

These include:

- process changes,
- water reuse,

- regeneration reuse, and
- regeneration recycling.

3.2.4 Using Water Pinch Analysis (WPA) as a tool for water management.

WPA is described by Brouckaert and Buckley (2003, p 1) as a technique to guide water and effluent management decisions while at the same time improving the efficiency of processes. It can be used in the initial design of the process, or as a tool to guide process modifications due to changing circumstances (financial, process or environmental). WPA enables the minimum amount of water to be determined by considering the introduction of recycle loops and reuse cascades. WPA highlights the operations that should be investigated for the improvement of their internal efficiencies of water management. Gianadda (2002, p ii) cautions however that the WPA approach has limitations where a clear distinction between process streams and water streams cannot be made. The Chemical Engineers' Resource Page on the Internet (2004, www.cheresources.com) describes WPA as follows:

> *In view of rising fresh water costs and more stringent discharge regulations, WPA is helping companies to systematically minimize freshwater and wastewater volumes. WPA is a systematic technique for analyzing water networks and reducing water cost for processes.*

3.2.5 Using colour removal technology at the End of Pipe (EOP).

This technology is subject to:

- the availability of large-scale colour removal processes,
- the effectiveness of colour removal techniques on admixtures of dyes,
- cost benefits that colour and pollutant removal achieve especially with water recycling,
- an investigation to determine the Best Practicable Environmental Option (BPEO) which suggests that some techniques produce more significant environmental impact (sludge production, landfill options, toxic breakdown products) than that of colour alone,
- space implications of new installations, and hence asset implications of EOP treatment, and
- the sector infrastructure impact, particularly on independent businesses, of significant control investment.

EOP colour removal technologies include;

- concentration technologies, such as adsorption and flocculation,
- membrane technologies such as reverse osmosis (which allows water to pass through the system but retains almost everything else from the waste stream), nano-filtration (which retains most pollutants inside the membrane but allows water and some small molecule salts and organics to pass through), ultra-filtration (which separates suspended matter and larger molecules in solution from the small molecules) and micro-filtration (which separates materials in suspension from those in solution) and dialysis (also referred to as continuous deionization),
- the use of adsorbents such as activated carbon, inorganic adsorbents, ion exchange resins, synthetic cellulose and other fibre-based bioadsorbents,
- employing destructive technologies such as aerobic and anaerobic digestion, and
- using chemical oxidation techniques.

Concentration technologies such as adsorption and flocculation can be applied either before or after biological treatment. Cooper (1995, p 12) points out that, at a sewage disposal works, such as the HWW, textile waste is diluted with domestic sewage and other non-textile industrial wastewater. The colour is thus present in a lower concentration, and pH changes to promote flocculation are much less practical in the larger volumes of mixed wastewater. With all of the textile mills in Hammarsdale discharging into the HWW it may prove impossible to identify the source of any particular dye posing treatment problems. The use of inorganic coagulants on dye wastes in admixture with domestic sewage is likely to be impractical owing to the high doses required, the large volumes of sludge produced, and the risk of floc carryover. Coagulation and flocculation is thus seen as an appropriate technology for application at the source of textile wastewater. Cooper (1995, p 13) comments further that the possibility remains that sewage treatment works may provide or contribute to a practical and economic solution for colour removal. However, with the wide range of conditions encountered, particularly in respect of dye types, seasonal and fashion production cycles and percentage of coloured effluent in admixture with sewage, it is unlikely that a single solution will be developed. The adoption of colour removal at sewage treatment works has to be dependent on their being no detrimental effect on traditional sewage treatment processes or on the receiving watercourse, either by the effluent discharge or by any storm water provisions. Moreover, should colour removal be undertaken, it will be in addition to the usual sewage treatment processes on which trade effluent charges are based. Inherent in the provision of a colour removal scheme will be an additional charge to cover these additional pollutant-specific costs.

3.3 The recommendations made by Gilfillan (1997):

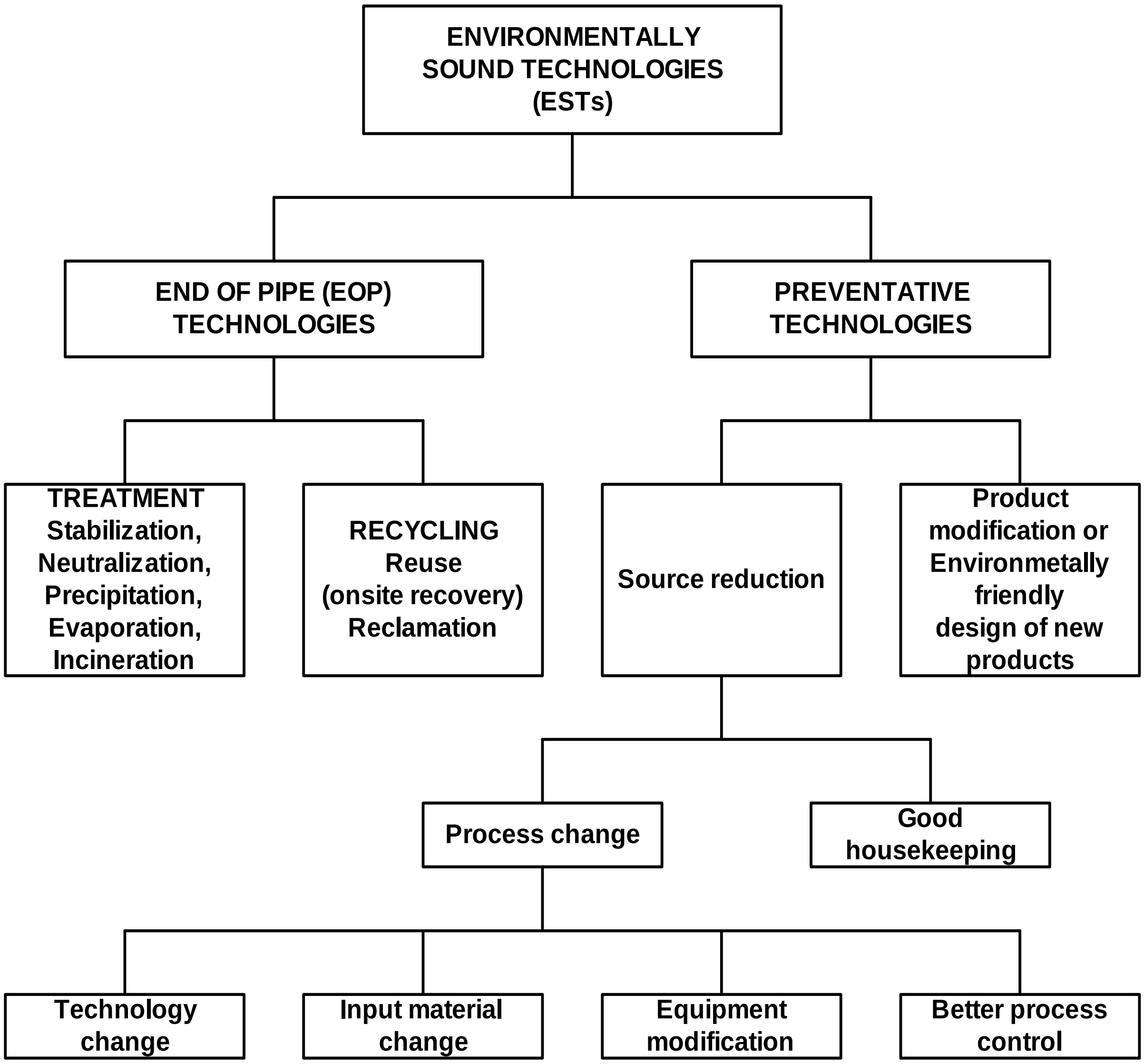
Following a detailed factory analysis of TMA (as factory A), Gilfillan (1997, p 6.28) made the following recommendations with regard to solving the effluent colour problem.

- highly concentrated effluent steams should be segregated and pre-treated on site. This would require separate piping from dye ranges. The current flow of effluent through the pre-treatment tanks on site would have to be altered to allow for separate treatment of *coloured* and *clean* effluent,
- concentrated effluent may be treated using Fenton's Reagent, or using a flocculant followed by dissolved air flotation,
- *clean* effluent could be treated for colour reduction and reused,
- water flow meters should be installed on all machines using large volumes of water. A flow meter should be installed on the effluent outflow to allow for the accurate calculation of effluent volumes,
- the feasibility of mixing all dye recipes in one central mixing area and piping the dye liquor to the ranges should be assessed,
- cleanout liquor from the beam, jigs and jets should be stored in a side tank and reused,
- the final rinse water of disperse dyeing processes on the beam could be stored in a side tank and reused,
- the final rinse water from acid and disperse dyeing processes on the jets could be stored in a side tank and reused and
- the potential for reusing relaxer and singeing effluent should be investigated. Effluent could be filtered and stored in side tanks and reused on the same machines.

The methodology of assessments used by Gilfillan appears in *Appendix I.*

3.4 Categories of Environmentally Sound Technologies.

UNIDO (2004, p 100) reports that there are no comprehensive estimates of the relative contribution of EOP and CP to pollutant reduction. All that can be said is that treatment of conventional pollutants by EOP has accounted for most of the reduction to date. However such treatment and recycling are not long-run solutions. Natural systems have a limited assimilative capacity to dilute wastes. In areas where there is a heavy concentration of industry this capacity is exceeded easily. Wastes can impair human health, reduce the productivity of fisheries and agriculture and damage man-made materials. The level of treatment is often limited because only so much of production costs can be allocated for the treatment of wastes, which is a non-productive investment. Recycling often suffers from limited or unpredictable markets for its products. Both treatment and recycling generate further residues themselves, some of which may be more harmful than the original waste product. The CP approach is seen as a better alternative for avoiding and minimizing environmental problems by reducing pollutant generation while at the same time reducing production costs and sometimes even resulting in better-quality products. CP not only results in better environmental performance, but in many cases has direct financial benefits to companies. *Figure 3.2* shows the categories of Environmentally Sound Technologies.



Source: UNIDO

Figure 3.2: **Categories of Environmentally Sound Technologies.**

3.5 The dilemma faced by TMA regarding cost control:

Because of the prevailing inclement trading conditions, the need for cost control, and the need to be flexible concerning the type of dyeing (and colour range) required by the textile market (which is decidedly fashion conscious), TMA must address the following commercial considerations:

- equipment should be sized to the same flow rate per operating period,
- running costs should be based on the same operating period,

- the level of balancing capability,
- sludge disposal, transportation and licence costs,
- design installation, civil and commissioning costs,
- depreciation costs,
- utility and energy costs and
- the return on investment based on all capital items.

As Barclay, (2004, p 50) points out, even after the application of B.A.T. within the various manufacturing stages, waste will still be produced that must be treated and disposed of. At the request of TMA, a pilot-plant belonging to a vendor was installed at their existing effluent treatment plant in order to conduct colour removal and COD reduction trials using one of the ESTs, namely EOP. The findings in this regard appear in **Chapter 4**.

4 Findings:

These findings record the progress made by TMA towards reducing effluent volume and improving effluent quality in concert with the objectives detailed in section 1.3. Because the fabrics produced and dyed by TMA consist of different types of warp and weft fibres, TMA has not installed facilities to separate *clean* and *coloured* effluents as is the norm when single fibre type yarns are dyed. According to TMA the rate of fixation of reactive dyes differs from fibre to fibre and there is carryover into rinse waters when multi-fibred fabrics are dyed. For this reason it is difficult to exclude reactive water soluble dyes entirely from the dyehouse effluent stream. Consequently no concentrated reactive dye effluent has been collected at TMA for transport by road tanker to the MWW for anaerobic destruction. Some waste minimisation related measures were however introduced and the pay-off is described. Likewise, efforts were made to minimize water using small process changes. No water re-use, regeneration reuse or regeneration recycling was attempted. The concept of water pinch analysis was not explored at all. The only substantial effluent treatment measure undertaken by TMA was to host an EOP pilot-plant trial by a vendor in order to remove colour using adsorption and flocculation followed by cold soda ash softening, GAC 'polishing' and cation exchange softening. The reason for this interest was to justify the change from the UW trade tariff formula to the less punitive EWS trade tariff formula in order to achieve substantial monetary savings. This change can occur only when EWS is satisfied that the TMA effluent can meet the revised colour specification detailed in section 1.5. The results achieved by this EOP trial are discussed in detail and show that, with some regeneration reuse, savings can accrue to TMA from the inception of a service contract with the vendor.

4.1 Actions taken by Textile Mill A regarding waste minimisation:

TMA subscribed to the aims and principles of the Hammarsdale Waste Minimisation Club (HWMC) when it was formed during late 1998. The principal focus of waste minimisation was to quantify and minimize liquid effluent as it accounts for the largest portion of the pollutants from the textile industry. Among the aims of HWMC project, which was sponsored by the WRC were to;

- transfer the technology and experience gained by the Pollution Research Group at the University of Natal, Department of Chemical Engineering, Durban to the South African Textile Industry.

- enable the South African textile industry to implement its own waste minimisation and pollution prevention programmes.
- educate and train the textile industry employees in pollution prevention strategies; and
- enable the South African textile industry to be internationally competitive through the implementation of proactive and rational environmental management systems.

Barclay and Buckley (2002, p 2.3) state that there are two fundamental approaches to waste management. They are waste minimisation and pollution control (EOP). Of these, waste minimisation is the more effective as not only does it reduce the generation of waste, but it also results in savings to industry. Barclay (2001, p 1.2) pointed out that the approach adopted in promoting waste minimisation in Hammarsdale has shown that cost savings and environmental improvement can be realized simultaneously. The actual savings achieved by 2002 (i.e. within three years) by members of the club are illustrated in *Table 4.1*.

Table 4.1: **Summary of areas in which the Hammarsdale Waste Minimisation Club achieved savings.**

Area	Saving %
Energy	28
Effluent	25
Water	22
Raw materials	11
Other	11
Consumables	3

The main drivers for this success were cost savings, pressure from local authorities and to reduce pollution. Further, on average, savings accounted for between two and five percent of the annual turnover of these club members. Regarding the economic analysis of waste minimisation, Buckley and Barclay (2003, p 5) have listed the following salient points;

- the viability of many waste minimisation investments depends on economics,
- one must carry out a total cost assessment,
- direct costs must be taken into account. These include buildings, equipment, utility installations etc,
- indirect costs must also be taken into account. These include administrative costs, insurance, on-site pollution control etc, and

- liability costs such as penalties, fines, injuries etc.

Table 4.2 reflects the actual savings in ZAR achieved by TMA during the period from late 1998 to 2001.They can be taken as future annual savings at 2001 price levels.

Table 4.2: **The actual savings achieved by Textile Mill A.**

Area	**Value of saving (ZAR)**
Consumables	272 000
Water	212 400
Effluent	212 400
Raw materials	113 500
Energy	89 700
Other	0
Total	**900 000**

As recommended by Barclay and Buckley (2002, p A1) a scoping audit was done by TMA to identify where further savings could be made. *Table 4.3* reflects the results obtained:

Table 4.3: **The results of the scoping audit done by Textile Mill A.**

Materials and services	**Indexed cost (solid waste disposal = 1)**	**Scope to save (%)**	**Scope to save (ZAR)**
Dyes	1 350	5	67.5
Primary yarn	1 300	5	65.0
Mains water	13	50	6.5
Effluent charges	13	50	6.5
Chemicals	95	5	4.8
Electricity	31	15	4.7
Packaging	16	20	3.2
Coal	12	20	2.4
Forerunners	6	20	1.2
Size	16	5	0.8
Solid waste disposal	1	30	0.3

The scope to save in respect of dyes and primary yarn were not considered in this dissertation. Only savings in respect of mains water and effluent charges were considered. The focus was on areas of high water use, on calculating key performance indicators for water use, on determining the scope for savings at TMA and on prioritising areas for further investigation.

4.2 The concept of an Environmental Scoreboard for benchmark cost comparison purposes:

Congruent with the competitive nature of the textile industry is the need to benchmark costs for management and staff motivation purposes. The costs per unit length of fabric produced are generated for comparison purposes. The method used to display such costs for comparison with international benchmarks is an Environmental Scoreboard (ES) such as in *Figure 4.4*.

Table 4.4: **An example of the Environmental Scoreboard used by Textile Mill A (fabric produced indexed to the monthly average for 2003).**

Utilities	Monthly average 2003	January 2004	February 2004	March 2004
Fabric produced	100.0	48.6	88.1	93.5
Electricity (kWh/m)	3.4	4.2	3.3	2.8
Water (l/m)	23.3	25.9	24.5	23.3
Steam (kg/m)	3.2	2.6	3.1	3.1
Effluent (l/m)	21.4	24.3	21.3	19.7

The ES, when updated regularly and displayed prominently on the premises at TMA, serves to reinforce the need to manage utility costs effectively. Regarding water and effluent costs it is important for TMA to achieve the savings indicated by the scoping audit. Without benchmarking, there is no means for gauging the competitiveness of TMA against its rivals, especially those which operate in countries with lax effluent discharge standards. Benchmarking also serves to reinforce the confidence of those owning equity in TMA. Benchmarking also highlights the need for focus on B.A.T. UNIDO (2004, p 98) emphasizes that plant-level data shows that even factories in the same location, using the same inputs to produce the same output and subject to the same regulatory regime vary widely in their pollution intensity, that is, pollution per unit of output. The main sources of this variation appear to be the technology and the industrial practices employed. The technology is largely a function of the age of the plant and the vintage of its capital equipment. The industrial practices, on the other hand, depend, in addition to technology, on the type of ownership of the plant, its size, its export-orientation and the regulatory and community pressures exerted on the plant to implement pollution-control practices.

4.3 The effect of different Trade Tariff Formulae on effluent discharge costs:

Kerdachi (2002, p 39) points out that the approach in South Africa for setting trade tariff formulae is full cost recovery including a return on assets which will provide a fair rate of return on the total capital investment required to finance wastewater infrastructure. A rate of return on assets can be justified from the point of view of there being an opportunity cost associated with the utilization of scarce capital resources for the development of conveyance and treatment infrastructure and this cost should be reflected in the tariffs. Notwithstanding this viewpoint, the UW trade tariff formula results in higher effluent charges than does its EWS counterpart. The UW trade tariff formula is the incumbent formula applied to TMA. Only when the colour has been removed from the effluent discharged by TMA in compliance with the standards set by EWS will the EWS trade tariff formula be applied.

Using the current UW and the EWS trade tariff formulae detailed in *Appendix F* to the mean values for COD, SS and ss detailed in *Appendix E* yields the following trade tariff formula costs:

4.3.1 The Umgeni Water (UW) trade tariff formula.

The cost is:

- COD = 1 014 mg/l
- SS = 94 mg/l
- Fixed charge = ZAR 3.90 /kl
- TTF cost = ZAR 4.76 / kl

4.3.2 The Ethekwini Water and Sanitation) EWS trade tariff formula.

The cost is:

- COD = 1 014 mg/l
- ss = 0.13 ml/l
- Fixed charge = ZAR 1.12 /kl
- TTF cost = ZAR 1.96 / kl

Saving = ZAR 2.80 / kl

From these figures it is apparent that there is a saving of 59% based on the COD, SS and ss values used. A comparison of the actual effluent charges paid by TMA with the potentially lower rate for the same effluent is illustrated in *Table 4.5*.

Table 4.5: **A comparison of effluent charges in South African Rands using the effluent characterisation figures in *Appendix E.***

Month	**Effluent charge (UW TTF)**	**Effluent charge (EWS TTF)**	**Total reduction %**
February 2003	110 000	45 000	59
March 2003	104 000	42 500	59
April 2003	101 000	41 500	59
May 2003	102 500	42 000	59
June 2003	131 000	53 500	59
July 2003	125 500	51 500	59
August 2003	107 000	44 000	59
September 2003	107 000	44 000	59
October 2003	111 000	45 500	59
November 2003	106 000	43 500	59
December 2003	110 500	45 500	59
January 2004	108 000	44 000	59
Totals	**1 323 500**	**542 500**	

From these figures it is evident that, had TMA been able to comply with the colour standard set by EWS, an annualised saving of ZAR 781 000 (in 2003 terms) would have been achieved. The potential exists for an even greater saving should the final effluent COD inset figure be reduced significantly.

4.4 The reaction of the management of Textile Mill A to this potential saving:

The management of TMA, having explored and utilised the savings revealed by the findings of the Hammarsdale Waste Minimisation Club, indicated its willingness to investigate the possibility of treating its raw textile effluent on an EOP basis in order to find a cost effective method of removing colour. An incentive sought by TMA was to implement regeneration reuse to recover water from the effluent suitable for selective reuse on its premises. TMA agreed to allow a vendor to set up an EOP effluent treatment pilot-plant adjacent to the existing effluent treatment facility in order to pursue these objectives. This was done during

May 2004. The pilot-plant was utilised continuously for a period of four weeks with trained operators working in shifts. Monitoring was done on site using empirical test methods and in the laboratory of the vendor in Gauteng. Based on the findings of this trial, a comprehensive written report was submitted to TMA.

4.5 The setting up of an End-of-Pipe effluent treatment pilot-plant:

The effluent generated by TMA is shown in *Figure 4.1.*

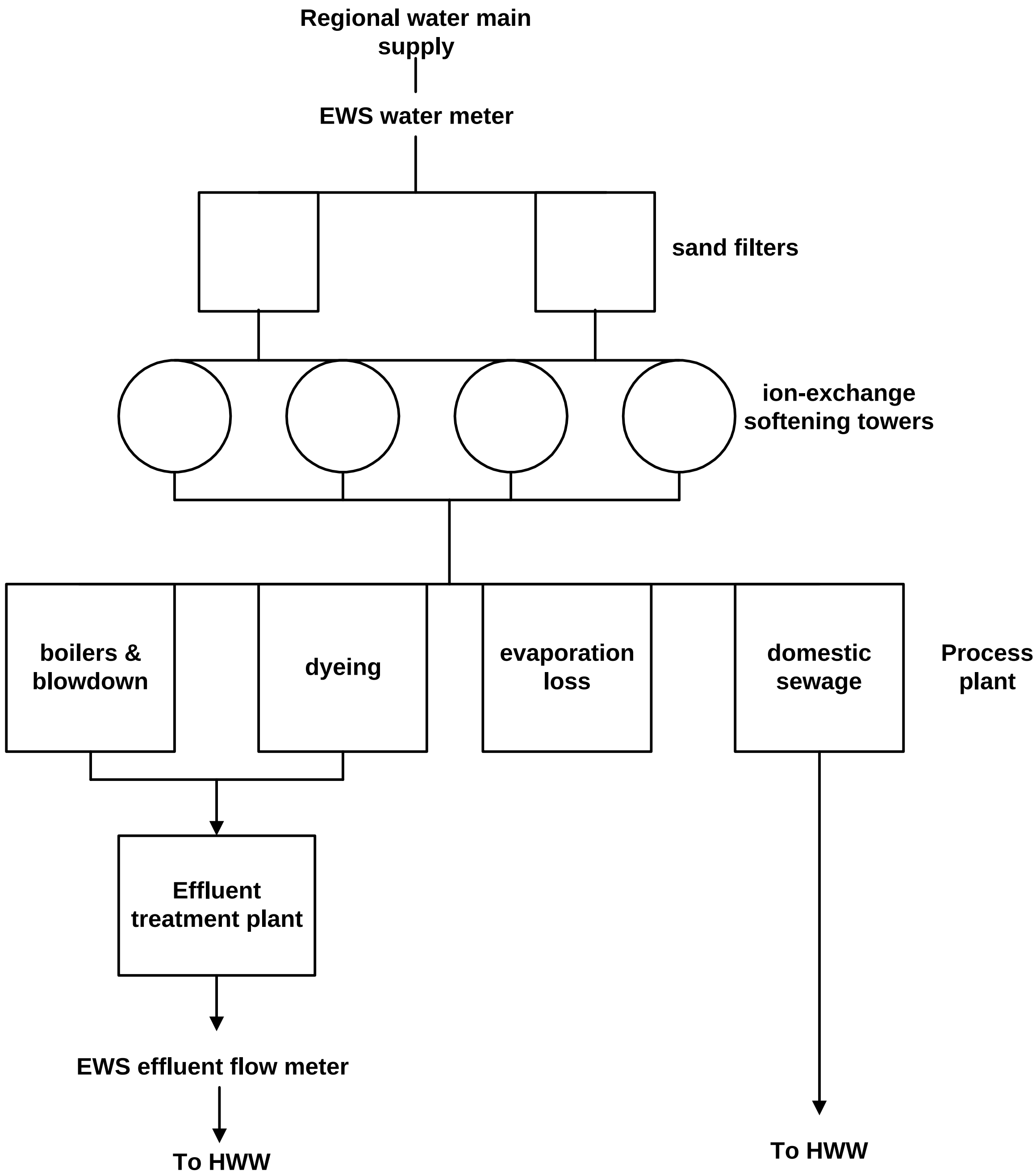


Figure 4.1: **The effluent generated by Textile Mill A showing sources.**

The effluent from the boilerhouse and the dyehouse (at 45°C) flows by gravity to the effluent treatment plant. Only the domestic sewage is reticulated directly to the HWW. The existing effluent treatment plant at TMA consists of two holding tanks plus a pH correction facility. This arrangement is depicted in *Figure 4.2.* The EOP effluent treatment pilot-plant shown in *Figure 4.3* was sited at the outfall from the two holding tanks and received effluent (at ambient temperature) of the same quality as that being reticulated to the HWW. This raw effluent was subjected to adsorption and flocculation followed by cold soda ash softening with the sludge so produced being dewatered. The resulting filter cake was sent to an approved landfill site. A final step was the polishing of the clarified effluent with GAC to improve its potential for reuse. Thereafter, the recovered water could be subjected to cation exchange softening or membrane separation using micro-filtration, ultra-filtration, nano-filtration or reverse osmosis in order to render it suitable for specific applications at TMA. No tests were conducted on clarified effluent using any of these membrane techniques.

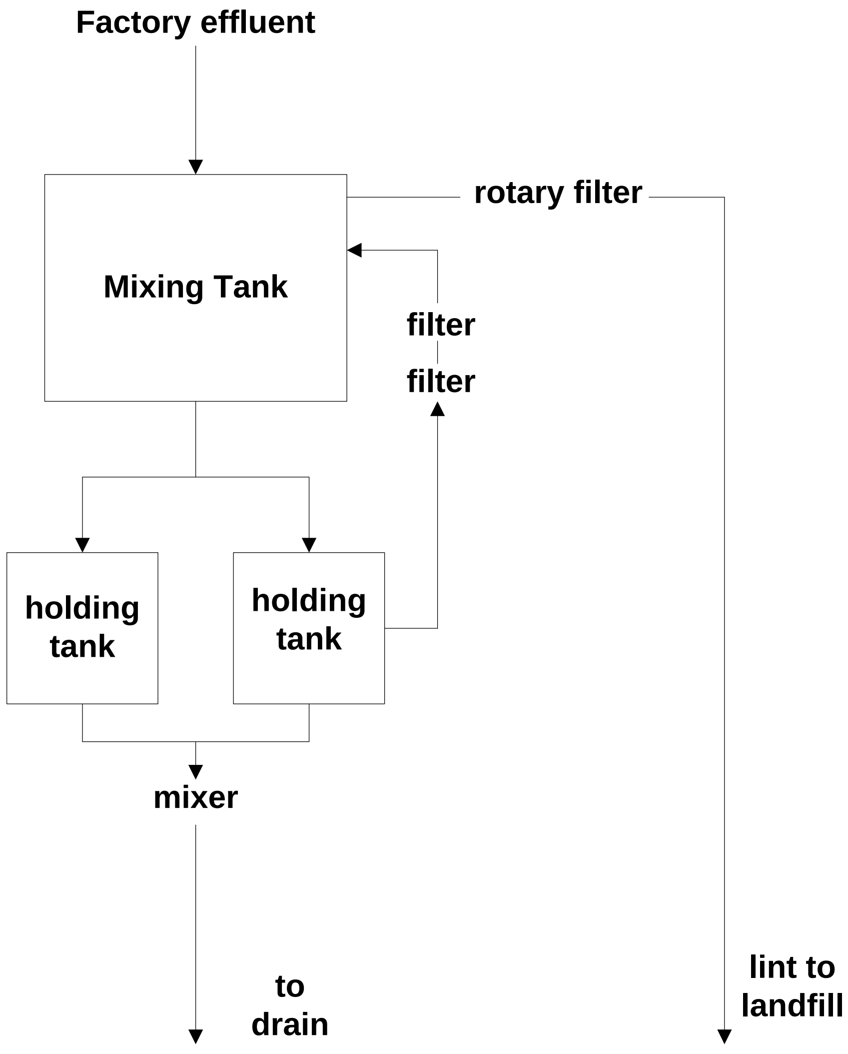


Figure 4.2: **The existing effluent treatment plant at Textile Mill A.**

The following steps were used with the effluent clarity and colour removal improving progressively:

- Effluent equalization
- pH adjustment
- Chemical precipitation
- Clarification.
- Cold soda ash softening.
- Dual media filtration.
- Dewatering and sludge disposal to landfill.
- GAC polishing.
- Cation exchange softening.

4.6 Description of the pilot-plant used:

The pilot-plant trial, with each party carrying its own costs, was agreed by TMA and the vendor to establish whether the raw textile effluent generated by TMA could be treated, at the EOP, to an acceptable quality to justify the introduction of the EWS trade tariff formula and to achieve regeneration reuse of water. The trial ran for four weeks using a sidestream from the normal effluent flow as influent to the pilot-plant. No other streams were introduced to this plant during the course of the trial.

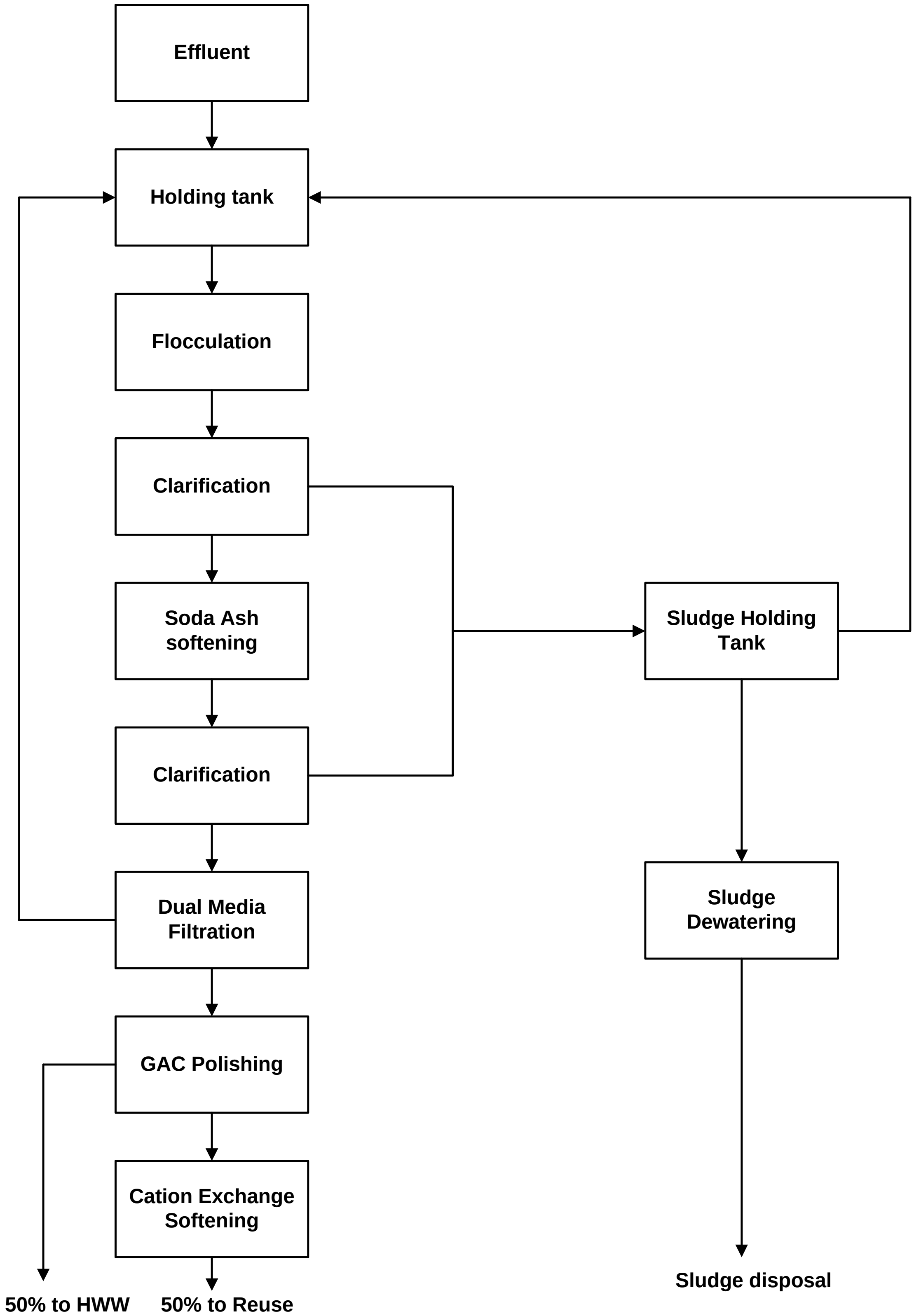


Figure 4.3: **Schematic layout of the pilot-plant**.

The unit operations undertaken are described in *Appendix J.*

A set of four skids carried the following equipment:

4.6.1 The clarification skid.

This skid carried:

- Chemical dosing pumps
- Floc column
- Sludge blanket clarifier (conical bottom)
- Soda ash softening clarifier

4.6.2 The tank skid.

This skid carried:

- Transfer pumps
- Mixers
- Rotameters
- Chemical dosing pumps

4.6.3 The dual medium filter skid.

This skid carried:

- Filter feed pump
- Sand and anthracite filter column
- Backwash facilities
- Pressure gauges
- Rotameters

4.6.4 The GAC skid.

- GAC column (200 to 300 l/d)
- Transfer pump
- Cation exchange resin column

Concentration technology employs chemically induced adsorption and flocculation to generate a precipitate which, either during its formation or as it settles, entrains other unwanted species such as colour. In general terms this technique requires pH control (using hydrated lime) and the addition of either an inorganic (ferric chloride solution) or an organic substance to cause precipitation. The supernatant liquor is then treated with soda ash to remove calcium and magnesium. The precipitates are then removed by settling to generate a sludge which is dewatered prior to being dumped on a suitable landfill site. The final treated water can be re-used, passed through a cation exchange softener, or reticulated to the HWW.

The rate of colour removal from raw textile effluents depends on the combinations of inorganic chemicals used. A limiting factor in the choice of such combinations is the quantity of sludge produced. The sludge disposal costs can be expected to increase markedly in years to come as a means of discouraging landfill disposal.

4.7 The results obtained using this pilot plant:

The raw effluent characteristics measured during this pilot-plant trial are shown in *Appendix K*. The trial proved successful in terms of COD reduction and colour removal. These results are tabulated in *Appendix L*. An Excel spreadsheet model was created to reflect the monetary benefit to TMA conferred by the EOP treatment of its raw effluent to partial re-use quality standards. The findings are tabulated in **Chapter 5**.

5 <u>Conclusions</u>:

Environmental and economic benefits do not always accompany each other and this EOP trial was skewed in favour of economic benefits (the environmental benefits having been stipulated by EWS in terms of the CAC philosophy). Indeed, Cooper (1995, p 88) reports that it is possible to remove anything from an effluent stream at a price. To install in-house treatment equipment that will remove colour from textile effluent and will permit repeated reuse of the water is an ideal to be pursued avidly. The conclusions reached after the concentration technology adsorption and flocculation trial described in this dissertation are detailed in terms of the objectives stated in section 1.3.

5.1 Technical merit validation:

The use of advanced adsorption and flocculation technology, as described in the UW report (UW,2000 p 12), to treat raw textile effluent on an EOP basis to remove colour and to reduce COD is validated subject to the ESTs shown in *Table 5.1*. The resulting ‘polished’ and cation exchanged softened recovered water is suitable for reuse by TMA as either cooling water, boiler make-up water or dyehouse rinse water. There is also scope for purifying recovered water to primary dyehouse standard using either a demineraliser or membrane techniques.

Table 5.1: **The sustainability of Environmentally Sound Technologies.**

Option	Financial	Social		Environmental				
		Internal	External	Colour	Conductivity	Sludge	Sodium	Water saving
Do nothing	---	+	---	--	-	**o**	**o**	-
EOP technologies	++	+	++	+++	-	---	--	++
Preventative Technologies	+++	++	++	++	+	+	++	+

Key: **o** no effect, + positive effect, - negative effect

5.2 Commercial evaluation:

In terms of cost-effectiveness the EOP raw effluent treatment process has been shown to be viable when the cost of that process is less than the savings offered by the introduction of the EWS TTF plus the savings gained through recovering water for reuse. Because TMA does not wish to finance an EOP effluent treatment plant, a Build, Own, Operate and Transfer (BOOT) agreement between TMA and a vendor is mooted. Such an agreement will entail the following contractual obligations by the parties:

- The vendor shall finance, install, commission and operate the EOP treatment plant. The risk in terms of compliance with the permit requirements stipulated by EWS will be borne by the vendor. In return for this TMA will pay the vendor a monthly fee, of which the variable costs component will be escalated annually to cater for inflation.
- At the end of an agreed period the vendor will transfer ownership of the treatment plant to TMA and a management agreement at a reduced fee will be negotiated.

Ignoring the possible tax benefits to TMA of a five year term BOOT type agreement, the financial break-even point occurs at a water re-use factor of 43%. However, a realistic factor is 50%. The savings to TMA should 50% of the raw effluent flow be recovered for re-use with the balance being reticulated to the HWW is illustrated in *Table 5.1*.

Table 5.2: **The savings to Textile Mill A should a BOOT type agreement result in 50% of the raw effluent flow be recovered for re-use.**

Year	Cost without BOOT (ZAR)	BOOT fee (ZAR)	Management fee (ZAR)	Savings (ZAR)
2005	1 710 000	1 627 000		83 000
2006	1 880 000	1 718 000		160 000
2007	2 070 000	1 814 000		248 000
2008	2 260 000	1 917 000		348 000
2009	2 490 000	2 027 000		460 000
2010	2 730 000		916 000	1 816 000
2011	3 000 000		993 000	2 000 000
2012	3 300 000		1 077 000	2 220 000
2013	3 600 000		1 168 000	2 450 000
2014	4 000 000		1 267 000	2 710 000

The assumptions made are:

- Monetary values are expressed at 2004 levels.
- The monthly raw effluent flow rate is 15 700 m^3.
- Uses can be found for the recovered water. In this regard *Appendix M* illustrates the suitability of the recovered water for use in cooling water applications, and *Appendix N* illustrates the South African Water Quality Guidelines for Textile Industrial Water Usage. It is envisaged that the recovered water will be re-used in the following applications;

process cooling	=	450 kl
compressors cooling	=	1 320 kl
machine cooling	=	308 kl
chillers cooling	=	2 200 kl
rinse water	=	3 572 kl
total	=	7 850 kl per month

- A 2003/4 mains water cost of R4.49 per kl.
- The EWS TTF is applied.
- The TMA cost without BOOT is escalated at 10% per annum.
- The BOOT fee is escalated to 2009 at 5.5% per annum.
- At the end of 2009 ownership of the effluent treatment plant passes from the vendor to TMA.
- A management fee from 2010 to 2014 is escalated nominally at the rate of 8.5% per annum. This fee covers labour, supervision, chemicals, repairs and maintenance, technology updates and risk of compliance. Contractually this rate will be linked to the ruling Consumer Price Index.

Table 5.3 shows the content of *Table 5.2* at present values assuming an inflation rate of 7%. These present value figures were obtained by applying the following formula:

$$PV = \frac{1}{(1 + r)^n}$$

where r = rate of interest (7%), and

n = number of periods (1 to 10 years)

Table 5.3: **The present day value of the savings to Textile Mill A should a BOOT type agreement result in 50% of the raw effluent flow being recovered for re-use.**

Year	Cost without BOOT (ZAR)	BOOT fee (ZAR)	Management fee (ZAR)	Savings (ZAR)
2005	1 600 000	1 521 000		65 000
2006	1 640 000	1 500 000		140 000
2007	1 690 000	1 480 000		202 000
2008	1 720 000	1 463 000		266 000
2009	1 775 000	1 445 000		328 000
2010	1 818 000		610 000	1 209 000
2011	1 870 000		619 000	1 246 000
2012	1 921 000		627 000	1 292 000
2013	1 996 000		635 000	1 333 000
2014	2 032 000		644 000	1 377 000

5.3 Compliance with the permit requirements of Ethekwini Water and Sanitation:

The raw textile effluent treated in accordance with the EOP procedure described in this dissertation will result in three end components which are:

- Recovered water which will be reused by TMA in place of an equal volume of mains water purchased from EWS,
- Effluent which will be reticulated to the HWW. This treated effluent will conform with the current requirements of the EWS permit for which TMA has made application.
- Filter cake which will be dumped responsibly at an approved landfill site.

It is probable that the permit requirements of EWS will become more stringent in future. The costs of further compliance will probably be offset by scope for increased savings to be realized from higher mains water and effluent disposal tariffs.

5.4 Options open to textile mills to avoid having an effluent colour problem.

The problem of colour in effluent is governed by the following factors;

- the types of fibres being dyed,
- the form of these fibres (i.e. whether as yarn or fabric),
- the types of dyes being used,

- the level of expertise in terms of dyehouse personnel,
- the types of dyeing technology used,
- the types of dyeing equipment used, and
- whether or not the textile mill is managed in accordance with the principles of CP.

After having instituted the principles of CP to the best of management's resources and abilities, all textile mills still facing an effluent colour problem should investigate the cost-effective implementation of an EOP treatment system.

6 Recommendations:

This chapter recommends that Textile Mill A should install an end-of-pipe type adsorption and flocculation effluent treatment plant to enable it to comply with the permit requirements set by Ethekwini Water and Sanitation and to save money on effluent disposal costs. The compromise between the polluter and society is also discussed. Finally, the use of membrane technology can be explored on a cost-effectiveness basis in order to improve the quality of the recovered water even further and so increase the water re-use factor to above 50%.

6.1 The optimal level of pollution:

According to Taviv et al (1999, E.5) there are numerous aspects of the *command and control* approach to pollution regulation which hamper the competitiveness of businesses. Prescribing technology is likely to reduce the competitiveness of a business as regulators would seem to be more concerned with pollution control than the commercial aspects of industry. Indeed, the experience of many countries has indicated that the *command and control* approach has often failed to provide cost effective and efficient solutions for environmental management. This has led to environmental governance provided by the discipline of economics-based measures to achieve acceptable levels of environmental benefit with simpler administration and lower control costs. In the context of pollution control this approach has become known as the Polluter Pays Principle. Studies, such as by Kerdachi (2002, p 7) have shown that this Principle has been used widely to design pollution or emission charges. In the field of water management such charges are referred to as *wastewater charges*.

The system of using permits granted by Ethekwini Water and Sanitation to producers of textile effluent in Hammarsdale is a measure of internalizing the pollution problem posed by colour in raw textile effluent. The incentive offered to each of the textile mills in Hammarsdale is the introduction of the more lenient Ethekwini Water and Sanitation Trade Tariff Formula in place of the Umgeni Water Trade Tariff Formula when specified raw textile effluent colour standards have been met. In the case of Textile Mill A, the Trade Tariff Formula cost difference (in 2004 monetary terms) is of the order of ZAR 781 000 per annum, which is a substantial sum of money to an industry experiencing very difficult trading conditions because of international currency fluctuations involving the South African currency. The cost to achieve this saving is however the amount of money to be spent to obtain the required discharge permit from Ethekwini Water and Sanitation. Having implemented most of the recommendations made by the Hammarsdale Waste Minimisation Club and having explored the concept of Cleaner Production, Textile Mill A decided to investigate end-of-pipe colour removal using adsorption and flocculation techniques. This dissertation describes an end-of-pipe trial undertaken by a vendor. The possible net savings are tabulated both in current, and in present value forms. These figures indicate that it is feasible to implement a cost effective end-of-pipe effluent colour removal plant at Textile Mill A and to recover at least 50% of the flow rate for selective re-use. However, in terms of ideology the adsorption and flocculation technology technique is not entirely eco-friendly as sludge has to be dumped at a suitable landfill site and soluble calcium chloride is introduced into the clarified effluent. This raises the issue of the optimal level of pollution to avoid adverse economic implications. Taviv et al (1999, p 2) avers that application of the Polluter Pays Principle requires that some kind of compromise be reached between the polluter and society (whose interests are generally represented by the government). The dual objectives of this compromise are to find a level of pollution where the costs of pollution are bearable to society and where the costs of using the resource are bearable to the polluter. In theoretical terms this point is referred to as the optimal level of pollution. It is not an actual level of pollution that can be readily quantified, but rather a conceptual level. In reality it should be the level of pollution that both industry and society can live with. As Taviv et. al. (1999, p 2) points out that the optimal level of pollution is not zero. It is where industry can continue to produce goods and the production of those goods with a reasonable level of environmental quality, which will maximize the welfare to society. In other words this optimal point is where a country or region can afford to trade-off economic growth with levels of pollution.

6.2 The economics of environmental protection and of preventative environmental protection.

Buckley and Barclay (2003, p 34) provide further insight into the economics of environmental protection. *Figure 6.1* illustrates the traditional view that environmental costs rise as environmental quality declines, and that technological costs rise as environmental protection increases. For inset values of environmental costs and technological costs the intersection of the two curves indicates an equilibrium point between environmental quality and technological costs (the costs to the polluter).

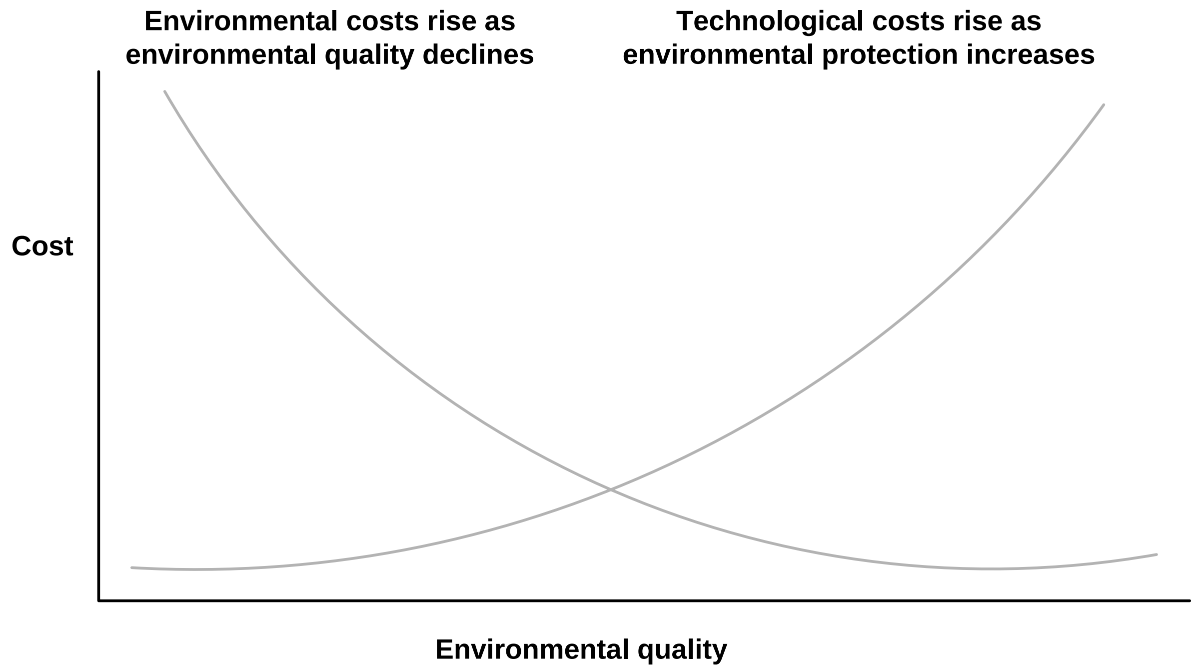


Figure 6.1: **The traditional view of the economics of environmental protection.**

From this figure it is evident that environmental quality will deteriorate as technological costs decrease and *vice versa*. In terms of the Polluter Pays Principle it is desirable to increase technology costs in order to improve environmental quality. In this manner the polluter is obliged to investigate improved technology and to invest in such technology to achieve Cleaner Production. The ideal is that such Cleaner Production will result in higher production efficiencies followed by enhanced profitability. This should benefit shareholders, workers, sales volumes to markets which are environmentally aware and the general public. The problem is however to initiate such investment in a conservative business environment. It is hoped that market forces, stricter environmental legislation and pressure from environmentalists will accelerate that process. What is sought is a negative trend in the Kuznets environmental degradation curve illustrated in *Figure 2.1*. Regarding environmental degradation, *Figure 6.2* illustrates that, as the technical costs curve moves to the left, so does the equilibrium point indicating that an increase in technological costs results in an improvement in environmental quality. The principles involved are;

- that, with increased inset costs by the polluter, the quality of the environment will be protected, and
- that Cleaner Production will assist textile manufacturers to contain the increase in inset costs and will result in less pollution.

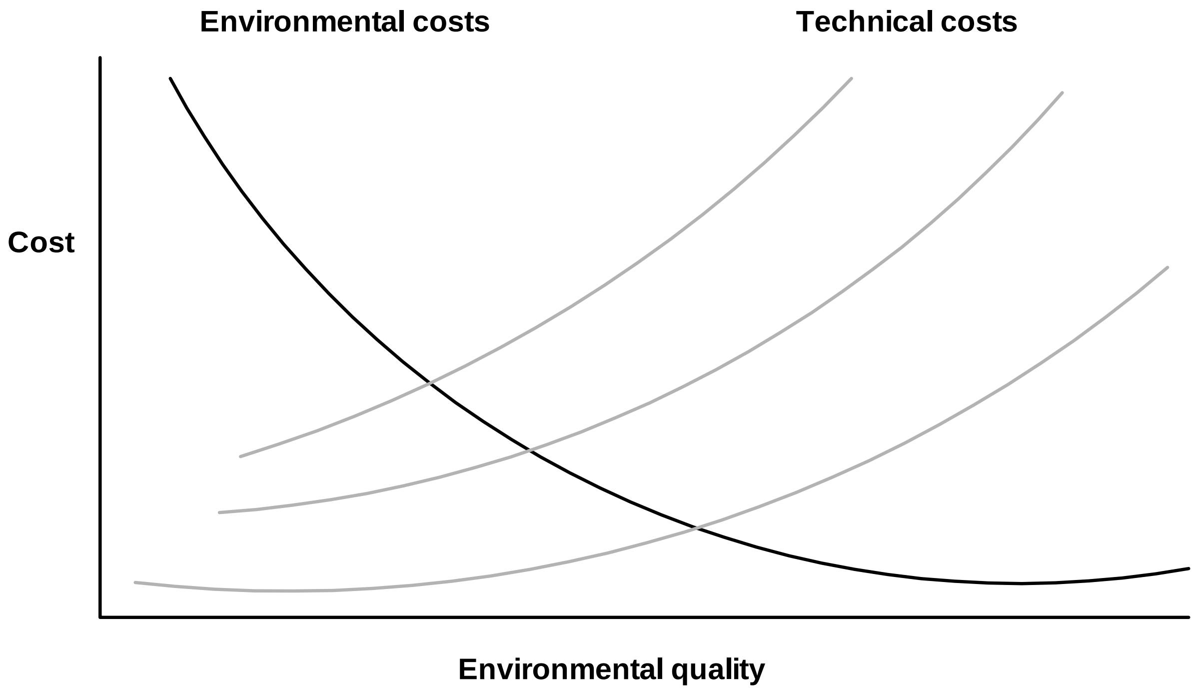


Figure 6.2: **The economics of preventative environmental protection.**

6.3 Recommendations regarding the further treatment of granular activated carbon 'polished' effluent to render it suitable for use as process water:

It is recommended that consideration be given by Textile Mill A to the investigation of the cost benefits of using membrane techniques to further purify the granular activated carbon 'polished' and cation exchange softened effluent described in this dissertation. Such membrane techniques are described in *Appendix O*. According to Cooper (1995) the principal advantage of using a membrane separation process is that concentration is achieved without any input of thermal energy, or a change of state, making the process energy efficient. Membranes provide a finite separation barrier which allows very dilute solutions to be concentrated and separated. High recoveries can often be achieved, and in some cases valuable product can be recovered from a dilute waste stream. Membrane systems, whether organic (polymeric), ceramic, micro-filtration, ultra-filtration, nano-filtration or reverse osmosis offer a range of unique separation capabilities in many different configurations and materials allowing a very wide variety of process applications. Compared with other separation or concentration systems, their space requirements are low and their modular construction and design allows relatively easy expansion.

6.4 The way ahead for Textile Mill A regarding on site effluent treatment and water recovery:

It is recommended that, in the context of the balance between economic viability and environmental responsibility, Textile Mill A should install an adsorption and flocculation end-of-pipe treatment facility followed by further processing of the recovered water to increase the recovery rate for re-use to over 50%.

6.5 The way ahead for the other six textile mills in Hammarsdale:

The effluent colour removal trial at Textile Mill A has been monitored closely by the other six textile mills in Hammarsdale. The content of the effluent at each of those textile mills varies in accordance with the types of fibres dyed, the types of dyes used, the installed machinery and the attitude of management to the principles of Cleaner Production. There can be no simple solution to the dilemma faced by each of these textile mills of removing colour from their effluent in order to comply with the Ethekwini Water and Sanitation permit conditions. It is hoped that work will continue to find a solution which enhances both economic viability and environmental responsibility. In this regard, the results of the Hammarsdale Work Plan (Remigi et al, 2003) will be of particular importance to the Hammarsdale textile mills.

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8 Appendixes:

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Appendix A

The Hammarsdale industrial estate

Figure A.1: **An aerial view of the Hammarsdale industrial estate.**

<u>Appendix B:</u>

The General Effluent Standard stipulated by the Department of Water Affairs and Forestry.

Ref: DWAF (2004, **www.dwaf.gov.za** **)**

- **Colour, odour or taste:**

  The wastewater or effluent shall not contain any substance in a concentration capable of producing any odour, colour or taste.
- **pH:**

  Shall be between 5.5 and 9.5
- **Dissolved oxygen:**

  Shall be at least 75% saturation.
- **Typical (faecal) coli:**

  The wastewater or effluent should not contain any faecal matter.
- **Temperature:**

  Shall be a maximum of 35^{o}C.
- **Chemical and biological oxygen demand:**

  Chemical not to exceed 75 mg/l after applying the chloride correction. Biological oxygen demand not to exceed 10 mg/l.
- **Oxygen absorbed:**

  The oxygen absorbed from acid N/80 potassium permanganate in 4 hours at 27^{o}C shall not exceed 10 mg/l.
- **Conductivity:**

  Not to be increased by more than 75 mS/m (determined at 25^{o}C) above that of the intake water.

  The conductivity of any water, wastewater of effluent seeping or draining from any area shall not exceed 250 milli-Siemens/m (determined at 25^{o}C).
- **Suspended solids:**

  Not to exceed 25 mg/l.
- **Sodium content:**

  Not to be increased by more than 90 mg/l above that of the intake water.
- **Soap, oil and grease:**

  Not to exceed 2.5 mg/l.

Table B.1: **Other constituents of the General Effluent Standard.**

Constituent	Maximum concentration in mg/l
Residual chlorine (as Cl)	0.1
Free and saline ammonia (as N)	10.0
Arsenic (as As)	0.5
Boron (as B)	1.0
Hexavalent chromium (as Cr)	0.05
Total chromium (as Cr)	0.5
Copper (as Cu)	1.0
Phenolic compounds (as phenol)	0.1
Lead (as Pb)	0.1
Cyanides (as CN)	0.5
Sulphide (as S)	1.0
Fluoride (as F)	1.0
Zinc (as Zn)	5.0
Manganese (as Mn)	0.4
Cadmium (as Cd)	0.05
Mercury (as Hg)	0.02
Selenium (as Se)	0.05
Nitrate (as NO_3)	25.0
Phosphate (as PO_4)	5.0
Calcium (as Ca)	200.0
Magnesium (as Mg)	200.0
Alkalinity (as $CaCO_3$)	500.0

<u>Appendix C:</u>

The overall rate of compliance of the Hammarsdale Wastewater Works with the General Effluent Standards.

Ref: UW (2002, p 58)

Figure C.1 illustrates that the **overall compliance of the HWW** during the period from July 2002 to June 2003 was only 74.4% in respect of the following determinands:

- COD and OA
- Conductivity
- Ammonia
- *Escherichia coli* (a micro-organism which indicates faecal contamination)
- Suspended solids
- Soluble reactive phosphate
- Total chlorides
- **Colour (<60% compliance)**
- Toxicity; guppies (a small freshwater fish *Poecilia reticulate*)
- Toxicity; *selenastrum capricornutum* (a green algae used as a biomonitor to assess the levels of nutrients or toxins in freshwater environments).
- Lead
- Sodium

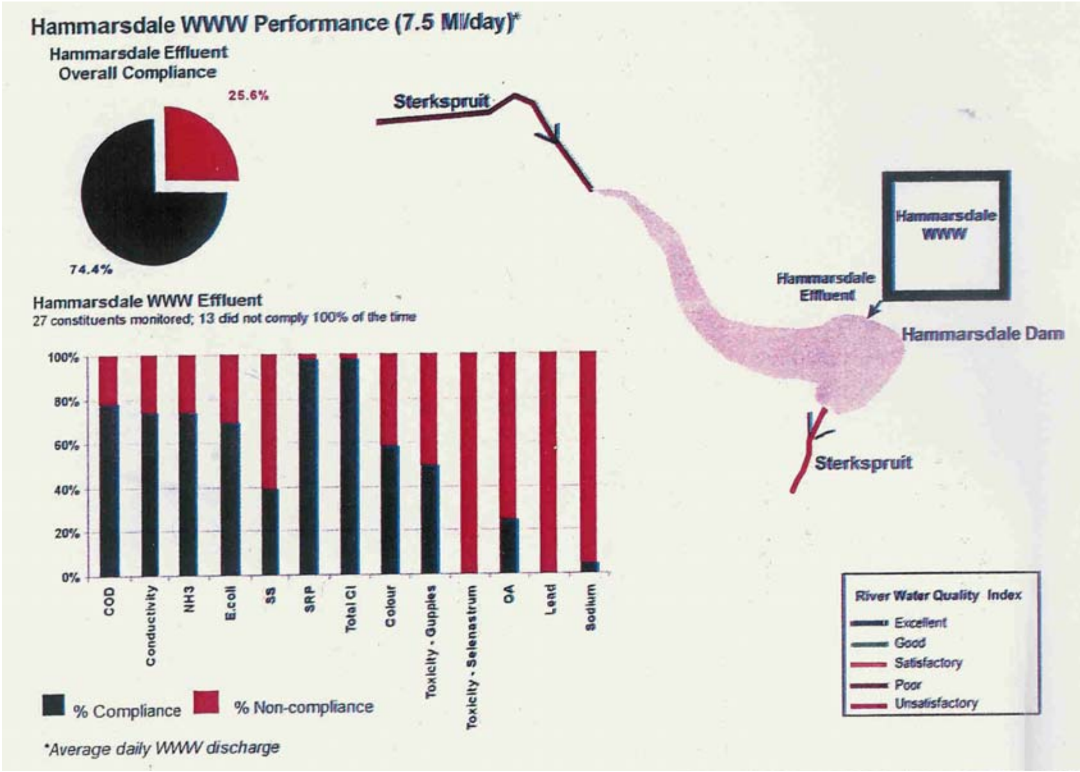

Figure C.1: **The overall compliance of the Hammarsdale Wastewater Works with the General Effluent Standard.**

Appendix D:

Further information regarding Textile Mill A:

Ref: promotional literature supplied by TMA, Hammarsdale.

1. Business philosophy.

   The business philosophy advertised by TMA is as follows:

   - TMA embraces quality at all levels, be it product, service or training.
   - People, customers and employees alike, remain our greatest asset, and we strive to serve them in the best possible way.
   - TMA is committed to protecting the environment, and awareness training forms part of our employee development programme.

2. The range of end products made using fabrics manufactured by TMA includes:

   - Aeronautical equipment such as parachutes, paragliders, hot air balloons and kites.
   - Apparel such as linings, schoolwear, corporate wear, uniforms, satins and sportswear.
   - Industrial articles such as coat base fabrics, filtration fabrics, reinforcing fabrics, scrims and airbags.
   - Military textiles such as rainwear, sleeping bags, ballistic resistant clothing, fire resistant garments and groundsheets.
   - Protective fabrics such as lint-free cleanroom wear, fire protective wear, metal splash protective wear, chemical protective wear, anti-bacterial protective wear and medical barrier protective wear.
   - Sport and leisure such as backpacks, car and boat covers, printbase, flags, waterproof fabrics, water resistant fabrics, flysheeting and ultraviolet protective wear.

3. Awards received:

   - 1994 awarded full membership of the Parachute Association
   - 1996 became accredited to Armscor
   - 1997 awarded ISO 9002 accreditation
   - 1998 Awarded ISO 14001 accreditation
   - 2001 awarded full membership of the Sector Education and Training Authority (SETA) for clothing, textiles, footwear and leather

Appendix E:

The characterisation of the Textile Mill A effluent.

Table E.1: **The characterisation of the Textile Mill A effluent based on historical data provided by Ethekwini Water and Sanitation and Sanitation.**

Date	COD mg/l	SS mg/l	ss mg/l	ADMI colour	Hazen colour
20/02/2003	1030	72	0	-	600
14/03/2003	717	56	0.1	-	357
24/04/2003	539	65	0	-	427
21/05/2003	650	48	0	-	594
25/06/2003	2155	94	0	-	918
30/07/2003	1820	146	0.1	-	1460
28/08/2003	830	110	0	-	1745
30/09/2003	860	70	0.3	936	1250
08/10/2003	945	-	0	-	-
15/10/2003	1310	140	0.5	1188	1844
22/10/2003	800	-	0	1074	1236
19/11/2003	675	104	0.1	563	842
20/11/2003	920	-	0.4	-	-
03/12/2003	814	156	0	896	1325
10/12/2003	1180	-	0.9	-	-
21/01/2004	912	70	0	1790	418
24/02/2004	1140	58	0	1855	2650
25/03/2004	952	122	0	1580	2175
Mean	1014	94	0.1	1235	1189
Maximum	2155	156	0.9	1855	2650
Minimum	539	48	0	563	357
Std Dev.	407	36	0	462	692
95% ile	1870	150	0.6	1832	2317

.

Appendix F:

Differences between the Umgeni Water and Ethekwini Water and Sanitation trade tariff Formulae.

Ref: Kerdachi (2002, p 3).

These formulae are based on the following equation which is derived from the Mogden Formula (which has been used in the UK since 1937).

charge to industrialist = fixed costs + treatment costs + conveyance costs

The Umgeni Water Trade Tariff Formula is as follows:

$$\textit{rands} \text{ per kilolitre} = X + \frac{V \times COD}{360} + \frac{Z \times SS}{225}$$

where	X	=	3.9 (fixed cost)
	V	=	0.285 (factor for treating organic strength)
	Z	=	0.145 (factor for treating suspended solids)
	COD	=	organic strength of mixed effluent (mgO_2/litre)
	SS	=	suspended solids (mg/litre)

The Ethekwini Water And Sanitation Trade Tariff Formula is as follows:

$$\textit{cents} \text{ per kilolitre} = X + \frac{V \times COD}{360} + \frac{Z \times ss}{9}$$

where	X	=	112.32 (fixed cost)
	V	=	29.53 (factor for treating organic strength)
	Z	=	29.41 (factor for treating settleable solids)
	COD	=	organic strength of settled effluent (mgO_2/litre)
	ss	=	settleable solids

Appendix G:

A description of the South African textile industry.

Barclay and Buckley (2002, p 1.3) describe the South African textile industry as follows:

The South African textile industry was established in the first half of the 20th century, and by 1939 was providing 3 500 jobs (Textile Federation, 1999). Major expansion took place within the industry between 1950 and 1960, and by 1960 there were 65 textile factories producing knitted fabrics, as well as cotton-based yarns and woven fabrics. This growth was not sustained over the next 2 decades, and in 1996 there were approximately 70 textile factories registered with the Textile Federation. It is the 6th largest employer in the manufacturing industry with 77 000 direct employees and 200 000 indirect employees in independent industries.

The textile industry is currently facing 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 by the Department of Water Affairs and Forestry especially in terms of colour, toxicity and salinity*
- *the introduction of ISO 14 000 and ecolabels*
- *new legislation*

With the lowering of the textile tariffs, the industry is faced with increasing competition and in order for it to survive, it must become export-orientated. This, therefore, exposes the South African manufacturer to the environmental pressures facing industries in Europe and the United States of America.

Appendix H:

A description of the European Eco-Label.

Ref: www.eco-label.com

The textile and clothing industry is facing new challenges following the globalization of the world economy and the competition of fast-growing Asian markets. In order to stay in the business, companies have to look for differentiating factors by designing high-value textiles and clothing. In an increasingly health and environmental conscious world a product that is able to prove that it is better for the environment and health by a trustworthy label can help textile manufacturers to make a difference in the eyes of customers. By adding an additional proof of quality it may help those manufacturers to compete on quality without necessarily increasing costs.

The European Eco-Label, which is the only sign of environmental quality both certified by an independent organization and valid throughout Europe, presents a unique opportunity to satisfy the expectations of customers.

Figure H.1: **The European Eco-Label**

The European Eco-Label indicates that:

- Reduced water and air pollution occurred during fibre production.
- During the whole production chain there was limited use of substances harmful to the environment and in particular to the aquatic environment and health.
- The garment is guaranteed not to shrink during washing and drying.
- The colour resistance of the garment is against perspiration, washing, wet and dry rubbing and light exposure is guaranteed.

Appendix I:

The methodology of assessment used by Gilfillan.

Ref: Gilfillan (1997, p 6.28)

The sources of water use and effluent generation were identified, and current disposal or treatment methods were investigated. Data on technological sophistication, process efficiencies, and waste generation, treatment and disposal were gathered in the following ways:

- A series of workshops for each machine utilising water were compiled and details on water consumption, heating and cooling, and effluent production obtained.
- Flow diagrams of the machines, showing flow of water, chemicals, and effluent were sketched.
- The health and environmental officer was interviewed to determine any existing environmental policies.
- Worksheets detailing number of employees, production and machinery were compiled.
- Worksheets on water consumption and effluent production were compiled.
- Worksheets on the various utilities (boilers, refrigeration, cooling towers, softening plant and air conditioning) were compiled.
- Typical recipes on each machine for the various qualities of fabrics and shades (light, medium and dark) were obtained.
- Safety data for the dyes and auxiliaries were noted.
- Consumption of dyestuffs and auxiliaries were obtained.

Appendix J:

Pilot-plant unit operations.

- The raw effluent was drawn as a side stream from the effluent stream at the point where it leaves the premises of TMA bound for the MWW.
- A hydrated lime slurry followed by ferric chloride solution were added to adjust the effluent pH to between 6.0 and 6.5.
- The resulting mother liquor was pumped to the sludge-blanket clarifier where the solids content of that liquor was allowed to settle out.
- The supernatant was then softened using soda ash.
- The clarified supernatant was then passed, via a launder to the dual medium filter to remove suspended solids.
- The underpass sludges were dewatered using a filter press.
- Some of the filtered liquid was then passed, for evaluation purposes, through the GAC column.
- Some of the resulting liquid was then passed through a cation exchange softener.

Appendix K:

Trial feedstock effluent characteristics (n = 30)

***Table K.1*: Trial feedstock effluent characteristics**

Determinands	Minimum	Average	Maximum
pH	7.0	8.0	12.0
Conductivity (mS/m)	0.5	1.4	4.3
Total dissolved solids (mg/l)	375.0	945.0	3 017.0
Suspended solids (mg/l)	9.0	28.0	93.0
Total hardness (mg/l as $CaCO_3$)	19.0	176.0	1 015.0
Calcium hardness (mg/l as $CaCO_3$)	5.0	151.0	1 004.0
Magnesium hardness (mg/l as $CaCO_3$)	0.0	24.0	75.0
Sodium (Na^+)	15.0	79.0	290.0
Iron (total Fe)	0.0	1.0	4.0
Chloride (Cl^-)	4.0	114.0	117.0
Sulphate (SO_4^{--})	25.0	294.0	600.0
Nitrite (NO_2^-)	0.0	103.0	149.0
Chromate (CrO_4^{--})	0.0	0.1	0.4
Silica (SiO_2)	50.0	149.0	266.0
Phosphate (total PO_4^{---})	1.5	3.0	2.7
Phosphate (ortho PO_4^{---})	0.0	3.0	6.0
Fluoride (F^-)	0.0	0.0	0.3
Turbidity (NTU)	32.0	573.0	3 038.0
P-alkalinity (mg/l as $CaCO_3$)	0.0	143.0	992.0
M-alkalinity (mg/l as $CaCO_3$)	127.0	348.0	1 116.0
COD (mg/l)	370.0	1 329.9	2 560.0

.

Appendix L:

Tabulated treated effluent characteristics (n = 30)

***Table L.1*: Tabulated treated effluent characteristics**

Determinand	**After GAC**	**After cation exchange Softening**	**Mains water**
pH	8.0	7.0	6.0
Conductivity (mS/m)	215.0	89.0	10.0
Total dissolved solids (mg/l)	1 146.0	565.0	54.0
Suspended solids (mg/l)	10.0	<10.0	16.0
Total hardness (mg/l as $CaCO_3$)	292.0	<1.0	ND
Calcium hardness (mg/l as $CaCO_3$)	239.1	<1.0	ND
Magnesium hardness (mg/l as $CaCO_3$)	54.0	<1.0	ND
Sodium (Na^+)	50.1	140.0	ND
Iron (total Fe)	<0.0	<0.1	ND
Chloride (Cl^-)	430.0	429.0	31.0
Sulphate (SO_4^{--})	241.0	241.0	13.0
Nitrite (NO_2^-)	1.0	1.0	ND
Chromate (CrO_4^{--})	<0.1	<0.1	ND
Silica (SiO_2)	9.0	9.0	ND
Phosphate (total PO_4^{---})	0.4	0.4	ND
Phosphate (ortho PO_4^{---})	0.2	0.2	ND
Fluoride (F^-)	0.5	0.1	0.1
Turbidity (NTU)	17.0	<15.0	ND
M-alkalinity (mg/l as $CaCO_3$)	174.0	75.0	ND
COD (mg/l)	110.0	<110.0	<10.0

.

Appendix M:

The impact of cycles of concentration after cation exchange softening and pH control at 8.0

Table M.1: **The impact of cycles of concentration and pH control at 8.0**

Parameters	Cycles						
	1.00	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**
Calcite	5.93	34.07	46.56	51.21	54.88	57.9	60.45
Aragonite	5.02	28.8	39.35	43.3	46.4	48.93	51.09
Anhydrite	0.0127	0.0286	0.0883	0.16	0.245	0.328	0.414
Gypsum	0.0121	0.0273	0.0842	0.157	0.233	0.312	0.393
Tricalcium Phosphate	0.0	0.0	0.1	0.2	0.4	0.6	0.9
Silica	0	0	0	0	0	0	0
Brucite	0.00802	0.0803	0.13	0.154	0.177	0.199	0.221
Magnesium Silicate	0	0	0.00	0	0	0	0

SIMPLE INDICES							
Langelier	0.974	1.91	2.12	2.2	2.26	2.31	2.35
Ryznar	6.07	4.62	4.26	4.11	3.98	3.88	3.79
Puckorius	5.08	3.62	3.27	3.11	2.99	2.88	2.79
Larson-Skold	1.16	1.17	1.97	2.95	3.91	4.87	5.81

98% Sulfuric Acid	0	0	435.51	964.76	1482.06	1987.08	2479.71

These simple indices are measures of evaluating the calcium carbonate stability of water. Should water be supersaturated in respect of calcium carbonate solubility it will have a tendency to cause scale formation at heat transfer surfaces.

Should water be undersaturated in respect of calcium carbonate solubility it will have a tendency to be corrosive to ferrous metal substrates.

All of the simple indices illustrated in the table above indicate that the recovered water, after cation exchange softening and pH control at 8.0, is suitable for use in cooling systems and for selective rinsing.

Appendix N:
The South African water quality guidelines for textile industrial water useage.

NOVEL SPINNERS S.A. (PTY) LTD.
/
NOVEL WEAVERS S.A (PTY) LTD.

REPUBLIC OF SOUTH AFRICA
Tel : (021) 573 9610
Fax : (021) 5739613

REG NO 1996/00184/07

27 / 07/ 2004

TO: IMPROCHEM
10 LONSDALE WAY
PINELANDS

ATTENTION: MR. WILLIAM PRETORIUS.

ENQUIRES: MR. G. W. ROBBERTS.
CELL: 082 884 1186
E-MAIL: garyroberts@noveldenim.co.za

1 REF: WATER QUALITY GUIDELINES

Dear Sir,

The following parameters will be required to meet the water quality for reuse in the factory for the dying process. Waiting on further details from the CSIR with regards to the basin discharge quality

PARAMETER	Unit	NOVEL	SAWQG	Basin Recharge
Chemical Oxygen Demand (COD)	mg/l	<50	NS	<50
PH @ 25^{o}C		7 – 8.5	7 – 8.5	7 – 8.5
Total Suspended Solids (TSS)	mg/l	<5	0 – 5	<5
Total Dissolved Solids (TDS)	mg/l	<500	NS	<500
Conductivity	ms/m	<50	10 – 70	<50
Chlorides Cl	mg/l	<300	NS	<300
Total Hardness (as $caCo_3$)	mg/l	<15	0 – 25	<15
Iron as Fe	mg/l	<0.2	0 – 0.2	<2
Sodium as Na	mg/l	<100	NS	<100
Ammonia as nitrogen		NS	NS	NS
Magnesium Mg	mg /l	<3	0.1	NS
Phosphate	mg/l	NS	NS	NS
Dissolved Organic Carbon	mg/l	<13	NS	NS
Ortho Phospate (P)	mg/l	<0.1	NS	NS

SAWQG = South African Water Quality Guidelines For Textile Industrial Water Usage.

NS = Not Specified.

Please contact Mr. G. Robberts should you wish to discuss any of the above.

Yours faithfully

………………..

Gary Robberts

Appendix O:

A description of membrane separation techniques.

Ref: The Nalco Water Handbook (1990, p 15.1)

Micro-filtration.

This technique separates materials in suspension from those in solution and its use after coagulation and flocculation can be considered. To its advantage it copes with textile effluents containing detergents and dispersing agents and it is relatively insensitive to temperature variations. Micro-filtration on its own is not a satisfactory end treatment, but may be used for the partial removal of colour and organics from effluent before it is discharged to waste, or before activated carbon treatment or reverse osmosis.

Ultra-filtration.

This technique is a development of micro-filtration which separates suspended matter and larger molecules in solution from the small molecules.

Nano-filtration.

This technique retains most pollutants inside the membrane but allows water and some small molecule salts and organics to pass through.

Reverse osmosis (hyper-filtration membrane technology).

This technique allows water to pass through the system but retains almost everything else from the waste stream. Conventional reverse osmosis for treatment of industrial effluents has limitations based on physical conditions such as pH and temperature, and on chemical properties such as membrane-chemical interactions and fouling. Newer thin film composite membranes have evolved and are much improved in relation to those parameters. Most reverse osmosis membranes are manufactured for use in desalinating seawater. Most certainly, any recovered water destined for either a cation exchange or demineraliser resin column would first have to pass through a reverse osmosis membrane.

An important consideration though is the disposal of the unwanted fraction of the stream fed to a membrane. This unwanted fraction will be a concentrated brine in the case of reverse osmosis.