COLOUR IN THE UMBILO RIVER

AN ENVIRONMENTAL INVESTIGATION

by

Judy Margaret Pitts

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Pollution Research Group
Department of Chemical Engineering
University of Natal
Durban

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DECLARATION

I hereby declare that this dissertation is my own work, unless stated to the contrary in the text and that it has not been submitted for a degree to any other University or institution.

J. M. Pitts

December, 1993

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ABSTRACT

Effluents from textile mills may colour watercourses despite treatment and the public assumes that they are observing raw, untreated pollution and thus, complain. Modern dyes have been synthesised to be resistant to biodegradation and thus refractive in biological treatment facilities. The Pinetown Colour Removal Committee was convened to address complaints arising from colour in the Umbilo River, which arises from textile dyeing effluent discharged from the Umbilo Wastewater Treatment Works. The Committee consists of representatives from the authorities and the Pinetown textile industry and decolourisation technologies are being tested, for implementation on-site or at the Umbilo Wastewater Treatment Works.

European legislation is becoming more strict and may result in the closure of many textile mills, unable to meet these requirements, especially with respect to colour limitations. The Americans have adopted a more pragmatic approach to colour discharged to watercourses and have left it to the local authorities to deal with, if and when it becomes a problem. Textile industries tend to be regionally aggregated, thus if mills have to close, unemployment will have an effect on the economy as a whole. The textile industry (including South Africa's) is under stress world-wide, due to low-cost imports from undeveloped countries which pay low wages.

The effects of coloured effluents in aquatic environments are not only aesthetic, as they can interfere with the transmission of sunlight and this manifests itself in the river, in a reduction in self-purification ability and a decrease in the numbers and biodiversity of flora and fauna. The latter phenomenon cannot be exclusively attributed to coloured effluents, as the silt load of the river and colourless, toxic constituents of discharged effluents must play an important role in reducing the quality of the aquatic environment.

Some dyestuffs have been determined to be hazardous and the risks involved are forming the basis of ongoing investigations. The hazard may not manifest itself in the dyestuff alone, but in the cocktail of chemicals and the processes with which it is involved. At the concentrations of dyes discharged to sewer from the Pinetown textile industry, which are then diluted with sewage, the toxicity risk may be negligible, but this requires further research.

An assessment was made of why complainants found colour in the Umbilo River offensive and most felt that it was toxic and responsible for degrading the environment. Those interviewed were unwilling to pay more for potable water to ensure that the Works decolourised the effluent, as they felt the polluter must pay. The complainants were encouraged by the formation of Committee, but were not included in the proceedings, which may cause problems at a later stage. Public participation in the Committee is essential to ensure that a solution to the problem of colour in the Umbilo River is resolved to the satisfaction of all interested and affected people.

Inclusion of the dye manufacturers in the Colour Removal Committee is essential, as their international parent companies have access to research on minimisation of coloured effluents. This includes new, improved dyes, dyeing techniques and decolourisation technology, in keeping with the philosophy of duty of care, which is now guiding environmental legislation in South Africa.

A colour limit of 80 Hazen units, which has been set for discharging effluent into the Umbilo River, is too stringent, as it relates to the colour of tap water. Visual determination of colour saturation in textile wastewater was found to differ from analytical results for different dye types and thus a single colour limit for all dye classes is unsuitable. Textile effluents are discharged to the Umbilo Purification Works in peaks of colour and volume and the treatment processes were found to reduce the colour to within a certain range, irrespective of incoming colour values.

The use of dilution, by coinciding discharge of highly coloured effluent with peak flows into the Works, is the most effective option for initial decolourisation. Chlorination, used to disinfect the final effluent at the Umbilo Purification Works, does not reduce colour of the wastewater and most of the colour removal occurred in the trickle filters and clarifiers.

The South African textile industry is important in terms of job opportunities and its contribution to the economy. If increased environmental standards are applied, the cost will probably be offset by retrenchments. South Africa is suffering from the problem of unemployment, but environmental degradation cannot be allowed to continue unchecked, so finding a compromise is essential.

PREFACE

The universe of geographical study may be divided into three realms: the nature of the environment, what we think and feel about the environment and how we behave in and alter that environment. These realms are everywhere interrelated. None can be understood in isolation... (Lowenthal, 1967)

This thesis is of mixed parentage: it forms part of a coursework masters degree in Environmental Management, which was initiated in the Geography Department, but formed part of the work being done on textile effluents, by the Pollution Research Group in the Department of Chemical Engineering. As most mongrels, (now known as a multi-disciplinary approach), it was derived from here, there and everywhere. It was written as a Geographical dissertation and as such, I have attempted to investigate the problem from all angles (holistically, as others would have it), as the environment consists of all the bits and pieces that make up life as we know it today, not only that which we can see, touch and hear, but that which involves feelings and attitudes. I was originally intending to complete the work by December, 1992, but due to time constraints the finishing touches were only made in December, 1993. The information however, is current up to the end of 1992, despite the continuation of the Committee's work and that of the Pollution Research Group.

GLOSSARY

ACETATE A manufactured fibre made from cellulose acetate.

ACID DYES Class of dyes used on wool and other animal fibres. If used on cotton or linen, they require a mordant. They are used on nylon for a good washfast result, which can be increased if treated with fixatives. They are comparatively small dye molecules with one or more sulphonic acid groups attached to the organic substrates.

ACRYLIC A manufactured fibre in which the fibre-forming substance is any long-chain synthetic polymer composed of (at least 85% by weight) acrylonitrile units. It is made in both filament and staple form.

ACTIVATED CARBON Charcoal, mostly of vegetable origin, of highly adsorbtive capacity. It is used for decolourising liquids and other adsorption purifications. Usually made by carbonisation and chemical activation.

ACTIVATED SLUDGE PROCESS Aerobic, biological effluent treatment process.

ANAEROBIC Describes a process involving micro-organisms which are capable of growing or metabolizing in the absence of free oxygen. Facultative anaerobes are those micro-organisms that grow under either aerobic or anaerobic conditions.

ANTHRAQUINONE COLOURANTS The characteristic chromophore is an anthraquinone itself, but the term is often extended to include other polycyclic quinone structures. They are often synthesised from anthraquinone derivatives and most are strongly coloured even in the absence of auxochromes. Anthraquinone derivatives are applicable as acid, basic, disperse, mordant, reactive and vat dyes.

AUXILIARIES Various substances which can be added to the dyebath to aid dyeing. They may be necessary to transfer the dye from the bath to the fibre or they may provide improvements in leveling, penetration, etc...

AZO DYES These are characterized by the presence of the azo group -N=N- as the chromophore. They are found in many of the synthetic dye classes and are used mainly on cotton and rayon fabrics.

AZOIC/NAPHTHOL DYES These are a type of azo compound formed on the fibre by initial treatment with a phenolic compound. The fibre is then immersed in a second solution containing a diazonium salt which reacts with the phenolic compound to produce a coloured azo compound. Since the phenolic compound is dissolved in a caustic solution, these dyes are mainly used for cellulose fibres, however, other fibres can be dyed by modifying the process.

BASIC DYES A class of positive-ion-carrying dyes known for their brilliant hues. Basic dyes are composed of large molecule, water soluble salts which have a direct affinity for wool and silk and can be applied to cotton with a mordant. The fastness of basic dyes on these fibres is very poor. They are also used on basic-dyeable acrylics, modacrylics and polyesters, on which they exhibit reasonably good fastness.

BIOCHEMICAL OXYGEN DEMAND (BOD) The amount of dissolved oxygen required by aerobic and facultative anaerobic micro-organisms to stabilize organic matter in sewage or water. It is therefore an indicator of the amount of organic matter in water and the BOD_5 test is performed over five days.

BIOLOGICAL TREATMENT The use of micro-organisms in a wastewater treatment, to achieve pollution reduction prior to discharge, for example, activated sludge process or the use of trickling filters.

BLEACHING Any of several processes to remove the natural and artificial impurities in fabrics to obtain clear whites for finished fabric or in preparation for dyeing and finishing.

CATIONIC DYES See basic dyes.

CAUSTIC A strong alkali (sodium hydroxide) used, for example in mercerising.

CELLULOSE FIBRES Fibres composed of or derived from cellulose (e.g. cotton, rayon, acetate and triacetate).

CHEMICAL OXYGEN DEMAND (COD) The amount of oxygen required to oxidise materials in a sample by means of a dichromate solution and may or may not be directly related to the BOD value, as COD is not limited to organic matter.

COLIFORMS All the aerobic and facultatively anaerobic, gram-negative, non-sporeforming bacilli that produce acid and gas from the fermentation of lactose.

DICHROMATE A chemical widely used in the application of some dyes. It is also used in boiler water and is toxic.

DIRECT DYES are applied directly to the substrate in a neutral or alkaline bath. They produce full shades on cotton and linen without mordanting and may also be applied to rayon, silk and wool. They give bright shades but exhibit poor washfastness. Various aftertreatments are used to improve the washfastness of direct dyes.

DISPERSE DYES These are a class of dyes which are only slightly water-soluble originally introduced for dyeing acetate and usually applied from fine aqueous suspensions. They are widely used for dyeing most synthetic fibres.

DYE CARRIER This is a product added to a dyebath to promote the dyeing of hydrophobic synthetic fibres and characterized by the affinity for and ability to swell the fibre.

DYEING A process of colouring fibres, yarn or fabrics with either natural or synthetic dyes.

DYES Substances which add colour to textiles by adsorption onto the fibre. Dyes differ in their resistance to sunlight, perspiration, washing, alkalies and other agents; their affinity for different fibres; their reaction to cleaning agents and methods and their solubility and method of application. Dyes are commercial preparations containing only approximately 50% pure dyestuff, the rest is inert filler e.g. sugar and surfactants. There are various classes and types.

DYESTUFFS The chemical component of dyes that imparts the colour to fabric, usually a complex, organic compound.

EXHAUSTION During wet processing, the ratio at any time between the amount of dye or substance taken up by the substrate and the amount originally available.

FAECAL COLIFORMS Coliform bacteria that are of faecal origin

FASTNESS Resistance to fading, i.e. the property of a dye to retain its colour when the dyed (or printed) textile material is exposed to conditions or agents such as light perspiration, atmospheric gases, or washing that can remove or destroy the colour. There are certain fastness specifications for particular uses of textile materials.

FINISHING the processes through which the fabric is passed after bleaching, dyeing or printing, in preparation for the market or use, for example, heat-setting, napping, embossing... The term may also refer collectively to all the processing operations including bleaching, dyeing, etc...

FIXATION The process of setting a dye after dyeing or printing, usually by steaming or other heat treatment.

FLOCCULENT A chemical which enhances floc formation in the treatment of sewage or water. A floc is an aggregation of micro-organisms or other materials floating in or on a liquid.

HEAT SETTING The process of imparting dimensional stability and often other desirable properties such as wrinkle-resistance etc...

HUE The attribute of colours that permits them to be classed as red, yellow, green, blue or an intermediate between any contiguous pair of these colours.

HUMUS A mass of decayed animal and plant matter, black or brown in colour.

HYDROLYSIS The cleavage of a compound by the addition of a water molecule, the hydroxyl group being incorporated in one fragment and the hydrogen atom in the other.

HYDROPHOBIC Lacking affinity for, or the ability to, absorb water.

KNITTING A method of constructing fabric by interlocking a series of loops of one or more yarns. The two major classes of knitting are warp and weft knitting.

LETHAL DOSE 50 - LD50 The dose of a chemical or inoculum required to cause death in 50% of the species being tested.

LEVELING Migration of dye molecules leading to uniform distribution of dye in a dyed material. Leveling may be a property of the dye or it may require chemical assistance.

LIGHT FASTNESS The degree of resistance of dyed textile materials to the colour-destroying influence of sunlight.

MERCERIZATION A treatment for cotton yarn or fabric to increase its lustre and affinity for dyes. The material is immersed under tension in a cold caustic solution and is later neutralised in acid. The process causes a permanent swelling of the fibre and thus increases its lustre.

MORDANT A chemical used in some textile fibres to provide affinity for dyes, usually a metallic salt.

MUTATION Change in the sequence of nucleotides within a gene to a new sequence, resulting in change of the protein product encoded for by the gene.

NATURAL FIBRE A class of fibres (including filaments) of animal, mineral or vegetable origin.

NYLON Generic name for a manufactured fibre in which the fibre-forming substance is any long-chain synthetic polyamide having recurring amide groups as an integral part of the polymer chain.

OPTICAL BRIGHTENER A colourless chemical which when applied to the fabric absorbs the ultra-violet rays of light and emits them in the visible spectrum.

OXIDATION A chemical reaction in which a substance loses electrons or a hydrogen atom or gains an oxygen atom.

pH The measure of the acidity or alkalinity of a solution. It is defined as the negative logarithm of the hydrogen ion activity. $pH=7$ of water is neutral, $pH<7$ is acidic and $pH>7$ is alkaline.

PHOTOSYNTHESIS Synthesis of carbohydrates from carbon dioxide and water using the energy of light secured with the aid of chlorophyll.

PIGMENTS These are insoluble and do not penetrate the fibre but affix to the fabric surface by means of synthetic resins, which are cured after application to make them insoluble. The colours are bright, generally fast and used in printing fabrics.

POLYESTER A manufactured fibre in which the fibre-forming substance is any long-chain synthetic polymer composed of at least 85% (by weight) of an ester of dihydric alcohol and terephthalic acid.

POTABLE Of water - fit to drink; free of harmful chemicals, micro-organisms and toxins.

PRINTING A process for producing a pattern on yarns, warp, fabric or carpet, by any of a large number of printing methods. The colour or other treating material usually in the form of a paste, is deposited onto the fabric which is then treated with steam, heat or chemicals for fixation.

RAYON A generic name for synthetic fibres, monofilaments and continuous filaments, made from regenerated cellulose. Fibres produced by both viscose and cuprammonium process are classified as rayon.

REACTIVE DYES Dyes that react chemically with the fibre.

REDUCTION A chemical reaction in which a substance gains electrons or a hydrogen atom or loses an oxygen atom.

REFRACTORY A term used in connection with organic compounds indicating that they are non-biodegradable or resistant to biological treatment and degradation.

RETAINED SLUDGE That which is generated by aerated biological degradation of wastewaters.

SEWAGE Drainage water and excrementitious matter from houses, communities or industries. It is conveyed in sewers or drainage pipes usually to a treatment facility, prior to discharge to a watercourse.

SCOURING Removal of foreign components from textiles, usually by the use of alkalies or solvents.

SEQUESTRANT A chemical used to bind foreign metal ions and frequently used in dyeing, for e.g. EDTA.

SIZING The process of applying compounds to the warp yarn to bind the fibre together and stiffen the yarn to provide abrasion resistance during weaving, for e.g. starch.

SLUDGE The semi-solid part of sewage that has sedimented, or the floc which has formed and settled out during sewage processing.

SOLVENT DYEING A dyeing method based on the solubility of the dye in some liquid other than water, although water may be present in the dyebath.

STARCH Organic polymer used as a size and is highly biodegradable.

SULPHUR DYES A class of water-insoluble dyes which are applied in a soluble, reduced form from a sodium sulphide solution and which are then re-oxidized to the insoluble form on the fibre. They are mainly used on cotton for economical dark shades of moderate to good fastness to washing and light. They generally exhibit very poor fastness to chlorine.

SUSPENDED SOLIDS (ss) Amount of solids separated by filtration of a sample of wastewater.

SYNTHETIC FIBRES Fibres that are synthesised, not of natural origin.

TOTAL ORGANIC CONTENT (TOC) The total organic materials present in a sample of wastewater.

TOTAL OXYGEN DEMAND The amount of oxygen necessary to completely oxidize materials present in a sample of wastewater.

TOTAL SOLIDS Amount of residue obtained on evaporation of a sample of wastewater.

TUFTED CARPET Carpet produced by a tufting machine instead of a loom. These machines are essentially multi-needle sewing machines which push the pile yarns through a primary backing fabric and hold them in place to form loops as the needles are withdrawn. The loops are then either released for loop-pile carpets or cut for cut-pile carpets.

VAT DYES are a class of water-soluble dyes which are applied to the fibre in a reduced, soluble form. They are among the most resistant dyes to both washing and sunlight and are widely used on cotton, linen, rayon and other vegetable fibres.

WASH FASTNESS The resistance of a dyed fabric to the loss of colour or change in properties during home or commercial laundering.

WASTED SLUDGE Excess sludge generated in a wastewater treatment system that must be removed from the system and disposed of.

WOOL The term usually applies to the fleece of sheep, but also to that from lambs or the hair from the Angora or Cashmere goat, which has never been reclaimed from any woven or felted wool product. Wool may also be blended, particularly with synthetic fibres to enable the spinning of very fine or loosely twisted yarns with increased tensile strength or to produce ease-of-care properties.

WOVEN FABRIC A fabric composed of two sets of yarns, warp and filling, formed by weaving, which is the interlacing of these sets of yarns to form a fabric.

YARN A generic term for a continuous strand of textile fibres, filaments or material in a form suitable for knitting, weaving or otherwise intertwining to form a textile fabric.

YARN DYEING The dyeing of yarn before the fabric is woven or knitted.

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INTRODUCTION

1.1 BACKGROUND

Coloured effluents are common to many industrial processes and include the food, leather, printing and paint industries. Few of these coloured effluents persist after treatment at a municipal sewage works or other treatment facility. Upon discharge from most conventional treatment facilities, however, the coloured wastewaters emanating from textile and paper and pulp industries stain the receiving waters into which they are discharged.

Industrial waste effluents containing colour have an impact on wastewater treatment works and upon discharge to watercourses, have an effect on the aquatic environment and visual enjoyment by the general public. An industrial waste may have received a high degree of treatment, as measured by reduction in the suspended solids and biological oxygen demand (BOD), but with little effect on the colour. The observer on seeing the colour, is not aware that the pollution has been reduced or even treated. Such colour frequently persists for a considerable distance in the watercourse and is often used as an indicator of pollution (Nawar and Doma, 1989).

Textile industry wastewaters are complex and variable due to the batch nature of the processes involved. This has produced situations characterised by treatment plant upsets and difficulty in meeting discharge permit parameters (Straley, 1984). Those mills involved in dyeing, produce an effluent that is usually highly coloured, of variable pH and temperature, high in dissolved and suspended solids and organic load. The removal of colour from textile wastewaters is currently one of the most important environmental problems facing the textile industry world-wide.

According to Gupta et al. (1988), the aesthetically undesirable colour in untreated textile effluents is often used as an indicator of a high organic load. If discharged directly to a watercourse, this will increase the biological oxygen demand (BOD) of the receiving waters and thus disturb the aquatic ecosystem. Textile wastewaters may also contain heavy metals, which enter the waste stream from mordants, metallised dyes and dye oxidants; catalysts for resin treatment and acid fulling; sizing preservatives and impurities found in common chemicals. An example of the latter is mercury, a contaminant from the production process of sodium hydroxide, which is used in the mercerisation process in the textile industry (Feigenbaum, 1978). Metal complexes of some dyes degrade in the aquatic system and release toxic constituents to levels above the permissible limit. Some dyes used in the textile industry have been described as hazardous, with possible toxic, mutagenic and even carcinogenic effects. Dyes are being investigated to identify and quantify any effects on health, biological processes and aquatic environments (Shaul et al. (1986) Shaul et al. (1991), Schramm et al. (1988), Sewekow and Diesterweg (1991), Moll (1991) and Norman and Sneddon, (1991)).

Colour is not the only treatment problem resulting from the discharge of dyeing effluents, as dyes consist of other materials in addition to the colour molecule (dyestuff). Commercial disperse dyes usually contain 15 to 30 % dyestuff, while acid dyes are generally 50 % pure (Tincher and Robertson, 1982). Materials present in addition to the dyestuff, include dispersing agents, salts, sugar and other additives and reaction products. To prevent dyes from negatively impacting on the aquatic environment, treatment is required for coloured effluents to be able to be discharged to a watercourse.

Synthetic dyestuffs have been developed to be slowly biodegradable, to ensure that they do not decolourise when exposed to sweat, micro-organisms, washing, bleaching or light. Most dyestuffs will therefore not be effectively removed or degraded during biological treatment at a wastewater treatment works, due to the short retention times and the aerobic nature of the liquid treatment systems. A combination of biological and chemico-physical processes to remove colour is usually the most effective treatment method (Gupta et al., 1988).

A literature search (Pitts, 1991) on colour in aquatic environments revealed that the problem was found to occur wherever textile mills are aggregated. The threat of imminent closure of textile mills due either to pressures to comply with effluent regulations or the recent enactment of stringent legislation, is a global trend. In pursuit of better effluent quality, it is increasingly commonplace to find colour standards built into discharge consent conditions. In some countries, colour restrictions are already being legislated, with colour reduction targets being set for the future (Laing, 1991).

Up to a third of the United Kingdom's (UK) textile production and processing plants may be forced to close, as they cannot afford the kind of wastewater treatment required to meet the demands of forthcoming legislation. The next two years will be crucial for the textile industry as tougher standards set in the Environmental Protection Bill will have to be met by October 1993. Colour removal in the dyeing and finishing sector is the main goal of these regulations (Opie, 1991).

In Europe, the textile finishing companies face the task of complying with European Community (EC) directives, the North Sea priority substances list and public concern on colour in effluents. The cost of full compliance, according to the March Report (1990), will threaten many of the small and medium sized companies with closure. The report also states that strong public pressure is being exerted to prevent the discharge of coloured effluents to watercourses.

A number of textile mills in Seoul were recently closed and will only reopen once effluent treatment equipment has been installed. A Hong Kong dyeing works had its land lease confiscated after repeatedly polluting a river in the territory. To retrieve the lease, the company will have to pay a HK$ 5 million fine, HK$ 200 000 towards the clean up costs and post a bond worth HK$ 2 million to ensure that it removes equipment causing pollution and removes effluent from its underground tanks (Anon, 1991).

There appears to be no quick-fix solution or one that can be applied to all situations and each waste seems to require a tailored solution requiring a combination of methods (Alspangh, 1973). Thus all aspects of the particular problem must be investigated and then one or more of the treatment options available that suit the situation may be applied.

1.2 THE PINETOWN SITUATION

The Department of Water Affairs and Forestry (DWAF) claimed to have received approximately six complaints concerning colour in the Umbilo River between January 1988 and December 1990. On investigating the source, they traced the origin to the Borough of Pinetown's Umbilo Sewage Purification Works' (the Works) outlet into the river. The Works is unable to remove or degrade many of the dyestuffs used in the textile industry and thus the receiving waters are coloured. One of the complainants accused DWAF of *killing the river* (Gravelet-Blondin, 1991).

Umgeni Water prepared a report on a biological and chemical survey of the Umbilo River performed on behalf of the Department of Water Affairs and Forestry (DWAF) in February, 1989 (Holmes, 1989). Nine sampling points were selected, lying between the source of the river, in Motala Farm, (see Figure 1.1) and Cato Manor (beyond the

N2 Highway). In-situ measurements of temperature, dissolved oxygen, pH and conductivity were performed at each of these sites. Samples were also collected for chemical and bacteriological analysis.

The report (Holmes, 1989) stated that a reasonable diversity of aquatic life was detected at all the sample points. Little difference in the quantity and diversity of aquatic life between the sampling points was detected. Discharge of effluent from the Works into the Umbilo River was observed to cause a change in the colour of the water, from colourless to brown and slight foaminess was also noticed. Apart from these changes, the conclusion was made that there was little difference in water quality with respect to chemical and bacteriological criteria, above and below the Works. The effluent from the Works did not appear to severely affect the quality of the river downstream of the point of discharge (Holmes, 1989).

As a result of the continuing public pressure and the stricter policy of DWAF, the Borough of Pinetown was asked to implement steps to reduce colour from its discharge by May, 1991 (Colour Removal Committee, 1991). The Borough could either prosecute the textile companies or use a novel approach by negotiating the means to remove colour from the Works' wastewater. The latter option was pursued in the light of the present economic climate and the new policy of the Borough and DWAF which seeks co-operation not confrontation (Department of Water Affairs and Forestry, 1991).

The Pinetown Colour Removal Committee (the Committee) was convened in May, 1990 and chaired by the DWAF, to consider ways of solving the Umbilo River colour problem. It comprised representatives from the local textile factories, the Borough of Pinetown, the University of Natal (Pollution Research Group) and the Water Research Commission. The Committee resolved to commission a literature search on colour in aquatic environments (Pitts, 1991) and a study by Explochem Water Treatment, to consider methods for colour removal at the Works (Pinetown Colour Removal Committee, 1990). Previous work in this field by the Pollution Research Group has concentrated on colour removal at source.

1.2.1 The Umbilo River

The Umbilo River has three sources (see Fig. 1.1), one in Westmead and the other two are in the area of Richmond Farm, between Durban and Pietermaritzburg. The confluence of these streams is in the suburban area of Ashley, in the Borough of Pinetown. The river meanders through Queensburgh and Durban before being canalised in the suburb of Umbilo. It joins the Umhlatuzana Canal at Bayhead before flowing into the sea via Durban Harbour.

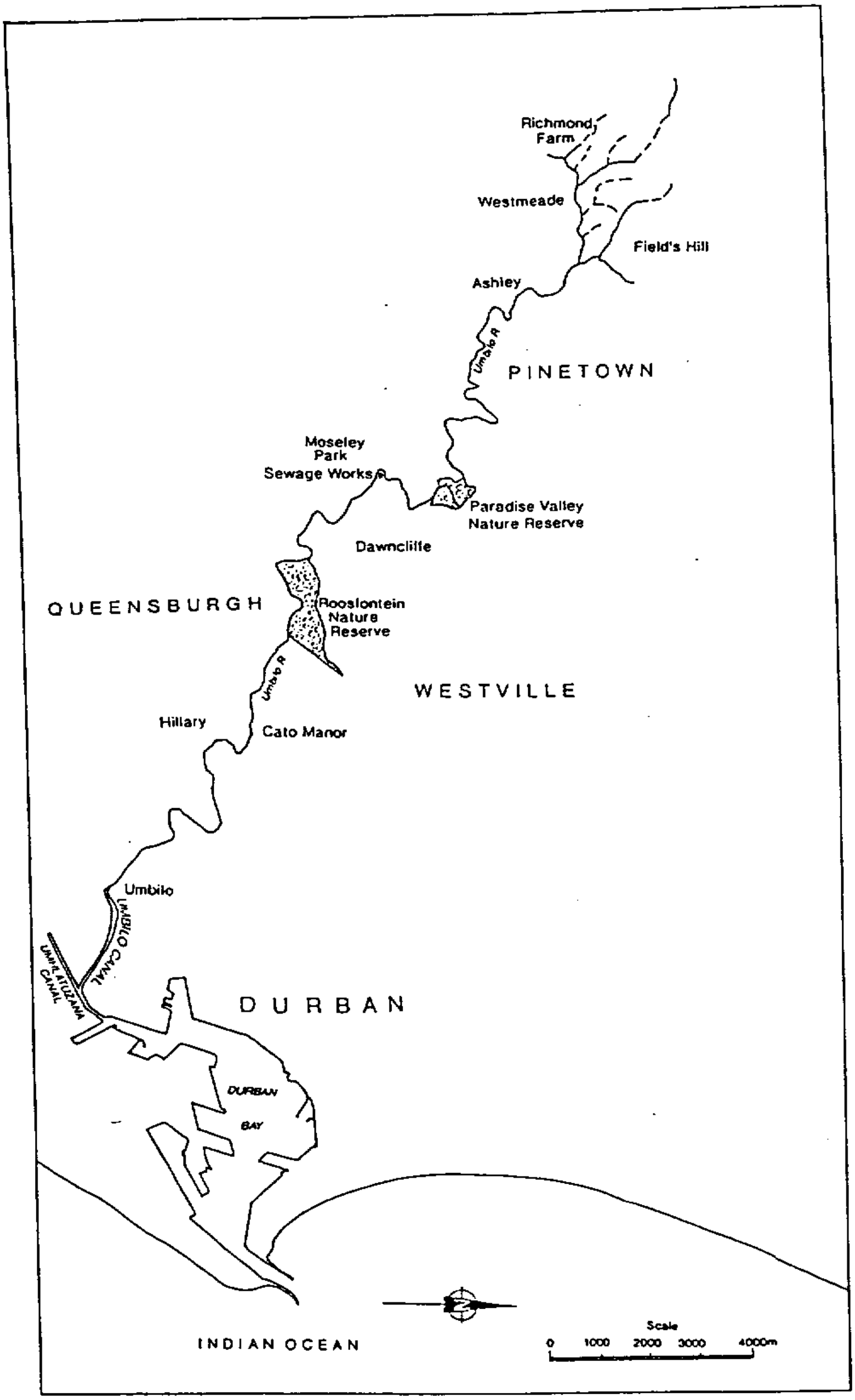

FIGURE 1.1: THE UMBILO RIVER

The extent of the uncanalized river downstream of the Works that is affected by the colour problem is approximately 10 kilometres. The areas affected by the quality of the water, are residential and recreational (Queensburgh Caravan Park and the Roosfontein Nature Reserve). The uses and extent of the river have to be taken into consideration when devising the range of the solutions for problem of colour in the Umbilo River. There is no water abstraction on a large scale for irrigation or any other purposes (Joubert, 1991), so the quality of water is set for human contact (swimming, paddling) and aesthetic criteria.

The Durban Metropolitan Open Space System (DMOSS) is a Durban City Council environmental project which is attempting to re-establish the natural environment within the Durban area (Roberts, 19**). It is an open space system linking parks and recreational areas by nature trails, mainly by corridors along river valleys. The Umbilo/Umhlatuzana River system begins at Umbilo Park (alongside the canalised section of the Umbilo River) and follows a trail which will eventually link up with the Roosfontein Nature Reserve, the Umhlatuzana River and the Stainbank Nature Reserve. The quality of the river environment, including that of the water, will therefore play a crucial role in the success of DMOSS.

There are four textile companies involved in the Pinetown industry and their locations are shown on the map in Figure 1.2. They are Fabrina, Ninian & Lester, Twistex and Universal Lace. Fabrina and Ninian & Lester dye mainly cellulose-based and polyester fibres, while Twistex dyes and prints carpet yarns and Universal Lace dyes lace and lingerie fabrics. The Works is sited along the banks of the Umbilo River below the Paradise Valley Nature Reserve, as shown in Figure 1.2 and receives industrial wastewater and domestic sewage, which are combined for treatment.

Colour in the Umbilo River is not a continuous phenomenon and is related to textile production schedules. The factories close over the December holiday period and some are working short shifts during the present recession. The river flow during the summer rainy season is high and the water is usually turbid, so colour is not always visible. During the dry winter months, the river flow is low and the water is clear, so the colour is most noticeable. According to the Umgeni Water survey (Holmes, 1989) approximately 50 % of the river's flow originates from the Umbilo Sewage Works in summer and 90 % in winter, when little dilution of the effluent occurs.

As the colour problem associated with textile effluents is not restricted to Pinetown or South Africa and no universal solutions have been found, DWAF is using the Pinetown problem as a case study for resolving similar colour problems in Natal (Gravelet-Blondin, 1991). Such areas include Durban and Hammarsdale, where textile industries discharge their coloured effluents to the municipal sewage works. These facilities have to comply

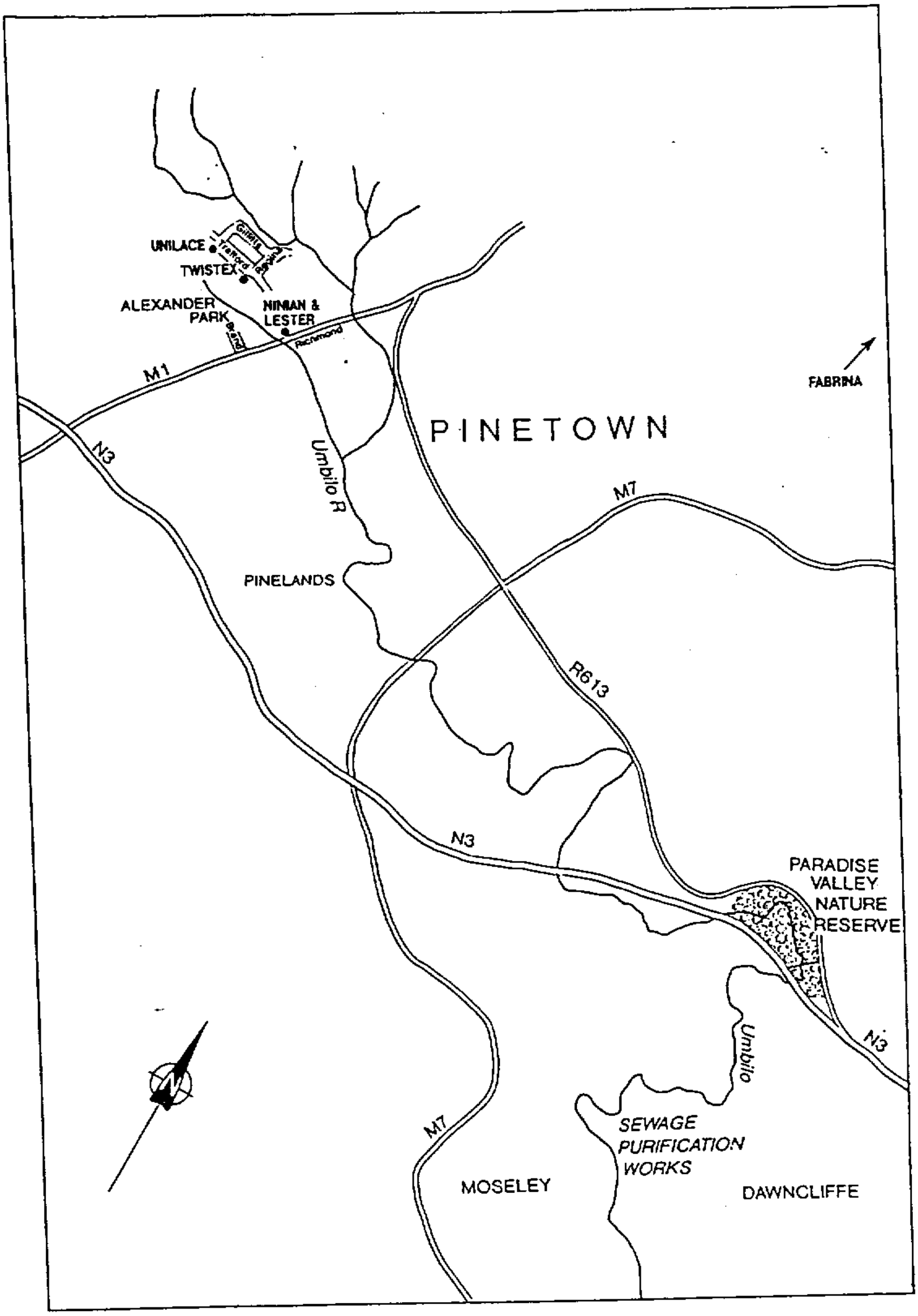

FIGURE 1.2: THE LOCATION OF THE PINETOWN TEXTILE INDUSTRY AND THE WORKS

with the conditions of the Water Act (43 of 1956, as amended) which prevents the discharge of wastewaters containing substances in a concentration capable of producing colour (Government Gazette, 1984).

The Trade Effluent Officer of Pinetown contended that it did not make sense to force a company to comply with strict standards and thereby risk its closure. Point source pollution such as this, is easier to control, with industry paying most of the cost, than the pollution emanating from diffuse sources, such as informal settlements. This is borne by tax payers and cannot be effectively controlled (Redlinghuys, 1991). DWAF has stated that it will not enforce a particular solution to the Umbilo River colour problem, if it would result in the closure of factories or lead to retrenchments. In a choice between different effluent disposal options, DWAF will in principle:

> *support the best option from an economical, technological, social, political and environmental point of view* (Department of Water Affairs and Forestry, 1991).

The Works usually receives complaints from residents whose properties border on the river or who use the river for recreational purposes, when the river is coloured red or purple. The other colours such as blue, yellow and green, do not seem to elicit objections, according to the Pinetown Trade Effluent Officer (Redlinghuys, 1991). Foam used to create a large-scale problem before the formulation of household detergents was changed. However, complaints concerning foam are still received downstream of the Works and the cause is often the detergents used by the textile industry (Redlinghuys (1991). Surface-active agents are used in textile processing and while many are biodegradable, others are biologically hard and at very low concentrations, have a synergistic effect on the foaming of surface waters, when traces of anionic detergents are present (Barnes and Dobson (1967). The abuse of storm water drains for the disposal of water used to clean cars at garages, for example, has also been implicated in foam sightings in the Umbilo River, according to records kept by the Works.

The Umbilo River colour problem has developed from three directions, according to Redlinghuys (1991). The Pinetown textile industry has expanded over the past decade and so have their effluent volumes. Related to this has been a change in fashions leading to an increase in the use of cotton reactive dyes that are especially resistant to biodegradation, which is the main treatment method employed at the Works. The third aspect has been the increasing global, environmental awareness of the public and the extensive coverage of pollution events by the media, especially on television, which brings environmental issues directly into the home. Recent international events include the Soviet Chernobyl nuclear accident, the fatal consequences of toxic chemicals leaking from a factory in Bophal (India), the Valdez oil tanker disaster off the Alaskan Coast and the consequences of the Gulf War.

In South Africa, the public's awareness of the environment has been stimulated by the controversies reported in the media, such as, seal culling, the proposed mining of the eastern shores of Lake St. Lucia and aquatic pollution by mercury from Thor Chemicals, near Pietermaritzburg. Colour and foam pollution of the sea by Sappi Saiccor, south of Durban, created a public outcry for many years. The company had to install a longer outfall for the discharge of the factory's effluents beyond the surf zone, which seems to have resolved most of the problem.

One of the most recent complaints concerning colour in the Umbilo River, was reported in a local newspaper under the heading *Changing Colours of the Umbilo* (Highway Mail, 1991), in which Pinetown residents voiced their concern about the discolouration of the River. The water turned *blood red* and later in the afternoon, changed to *royal blue.* The Works was alerted and the source of the pollution was traced to a blocked sewer. It was thus untreated effluent that was colouring the river, not the treated discharge from the Works.

Increasing world-wide pressure to decolourise textile effluents has resulted in studies, including that of the Pinetown Colour Removal Committee, being commissioned to investigate all aspects of coloured textile effluents. The National Rivers' Authority in the UK has sponsored a study by Leeds University to derive acceptable colour standards for watercourses and recommend a means of controlling coloured discharges which is both scientifically justifiable and legally enforceable (Ward, 1991). The University deliberately dyed a local river, to analyse the complaints received. The Industrial Technology Research Institute of Taiwan and the Kurabo Textile Company have signed an agreement involving the development of a treatment method for dyeing and finishing effluent with special emphasis on decolouring techniques for dyeing wastewaters (Wei, 1991).

Environmental issues no longer concern only the faunal and floral aspects of the environment and thus solutions to environmental problems must not address only the physical dimensions of a problem. A technological solution may be chosen to solve the colour problem in the Umbilo River, but if no cognisance is taken of why people find colour offensive, the complaints may continue and time and money will have been wasted. The complainants may associate colour with raw pollution and thus decolourisation of the effluents would be an appropriate solution. However, if the complainants relate the presence of colour in the river with environmental degradation and colour removal does not result in an improvement in the aquatic environment, the complainants may presume that the Committee instituted cosmetic changes. Hence, to solve the problem, the perceptions of those affected by the phenomenon must also be investigated to ensure that the technological solution is acceptable to all.

Colour in the Umbilo River may merely be an aesthetic problem, posing no threat to health, the treatment facility or the aquatic environment. In this case, a solution may be to impose stricter effluent standards preventing colour fluctuations in the river. Coloured effluent would still leave the Works, but would be confined to a certain colour range. The public could then be educated as to the source of the colour and the implications of its complete removal to the price of water, the textile industry, its employees and the economy in general.

If the colour were found to be toxic to the biological processes of the Works or the aquatic environment of the Umbilo River, then the dyes or chemicals involved will have to be identified and replaced with alternatives or the process altered, so that the chemicals are no longer required. If public health is at risk, the uses of the river will have to be evaluated and then either the river declared unsafe for recreation or the effluent treated to improve its quality. The latter is a costly alternative, especially in the present economic climate.

1.3 LEGISLATION

The limit set by the Department for colour in the Umbilo River is 80 Hazen Units. This is strict and similar to the colour of Durban's tap water. The Hazen method is usually applied to determinations of colour in natural waters and not industrial applications, so platinum-cobalt (identical to Hazen) standards were prepared and then analysed to determine the equivalent ADMI colour units. The 80 Hazen units limit was converted into American Dye Manufacturer's (ADMI) units with which the textile industry and the Works is familiar (see Figure 3.1).

A literature search was performed to determine international legislation and standards with respect to coloured textile effluents. Emphasis was placed on future trends in policy and public pressure in terms of textile colour in aquatic environments.

1.4 PERCEPTION OF COLOUR

An assessment of perceptions of colour in the Umbilo River was made, by surveying the attitudes of people who had complained to the Department, environmental groups and local authorities. The survey was an informal set of questions that developed with the conversations and the respondents were kept anonymous. School teachers using the Umbilo River for biological projects were also approached, as were residents who live in the vicinity of the river. Managers of the textile factories in Pinetown, representatives of the dye manufacturers and a spokesperson for a union representing textile workers were questioned on the implications of colour in the river, to the textile industry.

The survey was neither random nor intensive, but was used as a probe to investigate why people were complaining about colour in the Umbilo River and the perceived implications to the environment and the textile industry. It was also used as an aid to determine how extensive the technological solutions should be, to ensure that the problem is solved to the satisfaction of all those involved.

1.5 COLOURED EFFLUENTS

A literature search was performed to establish the extent of problems associated with coloured effluents and to determine the scope of treatment technologies available for consideration by the Committee (Pitts, 1991). Other non-technical options were also explored to ensure that an holistic approach to the problem was maintained.

Correspondence with international textile and dye manufacturing industries and the treatment facilities involved was made to establish decolourisation technologies in use, the success of operating plants and any limits that may have been set for colour in other countries. A literature search was also undertaken for this purpose (Pitts, 1991).

This dissertation should be seen as a preliminary investigation into the problem of colour in the Umbilo River and the recommendations made in the final chapter, should form the basis for the ensuing aspects of the study. The Committee continues to meet in their ongoing search for a feasible resolution to the problem and other research projects have been initiated to answer some of the questions raised in this thesis.

1.6 THESIS OBJECTIVES

The presence of colour discharged into watercourses does not imply that the effluent stream is untreated and the colour may persist, despite attempts to purify the wastewater from which it originated. This is an environmental problem facing the textile industry world-wide and the extent to which the effluents are decolourised is dictated by the financial situation of the country in which the industry is located. The South African situation is made more complex by the different standards of living experienced by its citizens and the more affluent sector of the population may demand a clean environment with the polluter paying, while the majority living below the breadline, demand employment, in spite of any long-term environmental implications.

The South African textile industry is in decline and has already retrenched thousands of workers. If it faces increasing pressures to improve its environmental performance, it may make more jobs redundandant or perhaps relocate to places where these pressures do not exist.

This thesis is an environmental investigation into the implications of colour in the Umbilo River. It therefore will endeavour to understand why people are complaining, the effects decolourisation of textile effluents may have on the aquatic environment, the textile industry and whether this will be enough to stop the complaints. The objectives of this thesis therefore, are to :

i) determine whether colour in the Umbilo River is merely an aesthetic problem, or if there may also be physical impacts on the aquatic environment. The complaints will be analysed to determine the underlying causes and to find out to what extent the solution must accomodate the complainants.

ii) investigate the limits on coloured effluents discharged to water courses, in terms of international legislation and trends and the South African situation. The latter will focus on the relevance to the Pinetown context, in terms of the economy, the treatment processes employed at the Works and the uses of the river into which the effluent is discharged.

iii) explore technological solutions to the problem, highlighting the options chosen by the Committee and treatments used internationally. Other alternatives will be examined that will encompass all the environmental concerns in an holistic manner. This will include the issues relating to the people involved, the physical environment and the socio-economic context in which the problem is inextricably bound.

Recommendations will be made on future studies required to solve the colour problem and how the Committee can ensure that the efforts they have made will be accepted by the public and especially the complainants involved.

CHAPTER
TWO

COLOUR AND THE TEXTILE INDUSTRY

2.1 THE SENSATION OF COLOUR

Colour is a subjective sensation and is experienced through the light-sensitive receptor mechanisms of the eye. Light is usually seen by reflection from, or transmission by an object, which modifies the quality of the light and produces the concept of a coloured object (Chamberlin & Chamberlin, 1980). Light is a change in the electromagnetic field surrounding the particles of matter, which is generated by the oscillation of the charged particles and travels through space as an independent entity.

Waves of electromagnetic energy consist of particles which display the energy and momentum characteristic of all elements of matter and can be described as a stream of particles. In the case of light, these are known as photons. The higher the frequency of light and the shorter the wavelength, the more energy contained in these photons. The quantum theory also explains the energy spectrum of an atom (or a system of atoms, for example a molecule), which can only assume certain definite values that are characteristic of that species of atom.

Light strikes matter and some of the light is re-emitted by the object in the form of photons, which are picked up by the eye. This light transmits information about the shape, texture and colour of the object. Other waves are absorbed and transformed into heat motion, depending on the characteristics of the solid object. The photons re-emitted by the object provide the initial stimulus for a specific visual sensation (Murch, 1972).

The reflected light ray enters the eye through the lens and after passing through the cornea and aqueous humor, enters the inner eye through the pupil. The amount of light allowed to enter is regulated by the pupil and the lens focuses the light on the sense cells of the retina. The actual light-sensitive cells are of two types, namely the rods and cones. These translate the input of light into nerve impulses which are transmitted up the optic nerve arriving eventually at the visual cortex of the brain. Rods are sensitive to very low light intensities and the cones provide information on detail, if the level of intensity of the light beam is great enough. The cones are thus the first analysers of colour, brightness and contour (Murch, 1972).

Hue is the aspect of perception commonly called colour, such as redness or blueness. When the wavelength of a stimulus is changed, the aspect that changes most strongly is the hue. The brightness is the perception of a patch of light which varies strongly with differing intensities and saturation refers to the purity of a hue, for example scarlet is more saturated than pink.

The two physical properties of light of primary interest in the study of perception are wavelength and intensity. Wavelength is a measure of the physical distance between the peaks of the photon waves. The wavelength of a light beam derives from and is in inverse proportion to the momentum of its photons, which is in turn, a function of the energy of the particles. The intensity of light depends on the number of photons in a particular beam and on the peak amplitude in the wave motion of the particles (Murch, 1972). The absorption spectrum is the proportion of incident light that is absorbed as a function of wavelength.

That portion of the wide spectrum of radiant energies to which the human eye is sensitive is quite small. When light from an ordinary lamp is passed through a prism and falls on a screen, a spectrum will appear, as shown in Figure 2.1. Each region of this spectrum reflects to the eye quanta of different wavelengths and if the intensity of the light is sufficient, the spectrum will appear coloured. Visual sensations are evoked by photon waves with lengths between approximately 420 and 700 nm. Immediately above the visible spectrum are the infrared rays (> 700 nm) and immediately below are the ultraviolet rays (< 400 nm) (Murch, 1972).

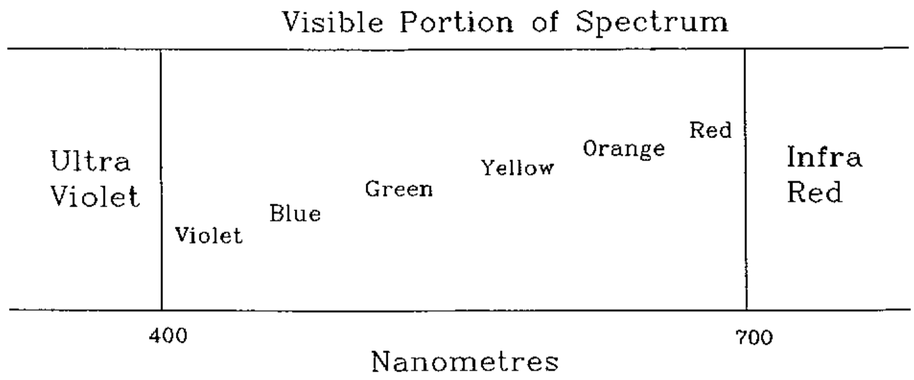

FIGURE 2.1: The Absorption Spectrum of Light

For the normal human observer, each colour corresponds to a different wavelength. If, for example, a spot of light of sufficient intensity of wavelength 578 nm is shown on a dark background, the spot will look yellow, and if the wavelength is 650 nm, it will look red. The colour of the spots therefore depends on the wavelength of light emanating from them (Cornsweet, 1970).

Seven entirely different visual sensations can be distinguished, namely red, orange, yellow, green, blue, indigo and violet. They merge imperceptably into one another and the sensation of colour is experienced when they strike the eye. Colour is actually the sensation realised by a person when light energy impinges on the retina of the eye, therefore, the phenomenon of colour is entirely subjective, as the sensation is created in the brain by the message stimulated by the impact of radiation of a particular wavelength on the nerves in the eye (Trotman, 1975). However, despite this, colour perception is amazingly consistent among people, such that over 90 % of the world's population have the same perception of colour.

TABLE 2.1 **Complaint Thresholds for Colour in Rivers** (After Pierce, 1991) OD of 0,05 = 1 ppm of dye		
WAVELENGTH (nm)	**PERCEIVED COLOUR**	**OPTICAL DENSITY (1 cm Cell)**
400 - 440	Violet	0,03
441 - 480	Blue	0,02
481 - 620	Green, yellow, orange	0,007
621 - 700	Red	0,005

Table 2.1 illustrates the complaint thresholds for colour in rivers, according to the wavelength at which the optical density (OD) is measured. An OD of 0,05 is equivalent to 1 ppm of dye (Pierce, 1991). It can be seen that at the wavelengths coinciding with the perception of red, less dye is needed to reach the threshold value, than for example violet or blue. A large wavelength range makes up the third class and their combined optical density is of the same order as that for the colour red.

2.2 DYES AND DYEING

The practice of dyeing textiles may have originated as early as 3 000 BC, in China and the application of dyes was a mystery and a closely guarded secret. After a long apprenticeship, skilled artisans became adept at extracting the active colourants from roots, seeds, berries, lichens, molluscs and insects and applying them to natural fibres. Progress in dyeing however, was severely limited by a lack of understanding of the chemistry involved.

The large-scale manufacture of coal gas in the early part of the nineteenth century, left large quantities of coal tar as a byproduct. The discoveries of naphthalene, aniline, quinolene and phenol in coal tar later stimulated German chemists to analyse coal tar fractions systematically and synthetic dyes were accidently produced (Holme, 1991). The discovery of the first synthetic dye and establishment of the first dye factory in the world was accredited to William Perkin. In 1856, while attempting to synthesise quinine from aniline sulphate with potassium chromate and extraction with ethanol, he obtained a brilliant purple solution containing the basic dye mauveine (Holme, 1991).

After the discovery of the diazo reaction in 1858, there were many developments in organic chemistry which laid the basis for the dyestuff industry. The isolation of primaries from coal tar, their conversion into chemical intermediates and the use of the latter to produce many coal tar dyestuffs, or aniline dyes on an industrial scale, revolutionised colour chemistry.

The first theory relating colour and chemical constitution was developed by Witt (1876, in: Remick, 1943) and consisted of an empirical relationship between chemical structure and dyestuff properties. All coloured organic substances known at that time contained unsaturated groups called chromophores. Molecules containing these groups are almost always yellow, but are not dyestuffs. When the chromophore is coupled with an auxochrome (such as NH_2, $NH(CH_3)$, $N(CH_3)$ and OH), it enables the molecule to dissociate electrolytically for binding with a substrate (Cooper, 1978). The auxochromes not only supplement the chromophores in the production of colour, but may also render the molecule soluble in water and assist in giving it an affinity towards the fibres (Trotman, 1975). On association with the auxochrome, the chromophore causes the colour to deepen and intensify and the molecule thus becomes a dyestuff, which is then capable of direct combination with textile fibres as a result of the basic or acidic nature of the auxochromes.

Dyestuffs impart colour to the material onto which they have been anchored, by selectively absorbing some of the wavelengths of light falling on the surface, however, only a limited number of organic molecules possess this property (Nunn, 1979). Dyes derive their colour from electron transitions between various orbitals and all organic compounds can absorb light energy, but in an unsaturated system, the electrons are more mobile and resonance causes absorption of lower energy light in the visible range.

The process of dyeing consists of three stages:

i) Migration of the dye from solution to the fibre interface accompanied by adsorption on the surface of the fibre.

ii) Diffusion of the dye from the surface towards the centre of the fibre.

iii) Anchoring of the dye molecules by covalent or hydrogen bonds, or other forces of a physical nature (Trotman, 1975).

All textile fibres, when immersed in water or aqueous solutions, acquire an electrical potential (positive or negative). Soluble dyes are either in molecular and partially ionized state, or exist in the form of ionic micelles. In the case of the acid and direct dyes, the chromophore-containing ions bear negative charges. To accelerate the migration of the dye molecules to the surface of the fibre, the bath temperature is usually increased to counteract the electrical potentials repelling the dyes and the fabric (Nunn, 1979).

Textile manufacturing and finishing processes have recently undergone major developments resulting in refinements in dyeing and printing techniques which considerably enhance the appearance of fabrics. In dyeing processes, in order to control the mobility of discrete dye particles in aqueous systems, special thickening additives have been developed to increase and maintain viscosity of the dyeing solution (Volesky & Roy, 1979). These additives are used by Twistex, one of the Pinetown factories, in the printing of carpet yarns and they pose their own particular treatment problems, due to the viscosity.

Dyes can also be classified according to their application and the categories are shown in Table 2.2. The basic or cationic dyes are hydrochlorides or salts of organic bases with the chromophore situated in the cation. They are used mainly for dyeing acrylic fibres (Groves et al, 1987).

The acid or anionic dyes are sodium salts of sulphonic or carboxylic acids and are used mainly to dye protein and polyamide fibres. The chrome dyes are a specific group of acid dyes which react with chromium salts to form a metallized dye (Groves et al, 1987). They improve the qualities of the dye, particularly in its light fastness, but this is usually at the expense of brightness, since they are duller than non-metallized dyes (Waring & Hallas, 1990).

TABLE 2.2
Dye Classes and Their Properties

DYE CLASS	PROPERTIES
Basic/cationic	salts/hydrochlorides of organic bases, acrylic fibres
Acid/anionic	sodium salts, protein/polyamide fibres
Direct	sodium salts of sulphonic/carboxylic acids, azo-compounds
Sulphur	organic compounds containing sulphur, cellulosic fibres - cheap, lack brightness, good wet-fastness
Azoic/Naphthol	insoluble pigments, cellulosic fibres, good wet-fastness
Vat	insoluble in water, soluble when treated with NaOH and a reducing agent, expensive & colour-fast
Disperse	suspended organic compounds, hydrophobic and synthetic fibres
Reactive	chemically combine with cellulose, for cold, continuous processes, good wet-fastness

The direct dyes are similar to acid dyes in that they are sodium salts of sulphonic acids. They are usually azo-compounds and have a direct affinity for cellulosic fibres (Groves et al, 1987) and are used for low cost requirements, but the result is a lack of fastness. Direct dyes are easy to apply, however the presence of chelated copper in many structures and the frequent need to apply cationic after-treating agents may increase effluent problems (Shore, 1991). However, as direct dyes may be readily removed by adsorbtion or precipitation and thus treatment solutions are available.

To dye inexpensive shades of good wet-fastness on cellulosic fibres, the sulphur dyes are used to produce heavy shades, however the colours lack brightness. Sulphur dyes, which give a high degree of colour to wastewater, are complex organic compounds of high molecular weight (Kogan et al, 1986) and the dyeing method is similar to that used for vat dyes. Sulphur dyes are usually dissolved in an alkaline solution, which serves as a reducing agent. Once this solubilised dye is applied to the fibre, it is oxidised in place to impart colour. The vat dye class consists of water insoluble pigment dyestuffs that are also converted to a soluble form under alkali reducing conditions.

Azoic dyes are water insoluble azo compounds produced *in situ* in textile fibres by the interaction of a diazo component with a coupling agent (Wareing & Hallas, 1990). They are principally used for dyeing cellulosic fibres on which they provide a wide range of bright hues. The actual hue produced is determined by the particular combination of diazo and coupling components used. Azoic dyes are essentially pigments, having little or no water solubility when formed in the fibre structure (Waring & Hallas, 1990).

Disperse dyes are suspensions of colloidal dyes with very slight aqueous solubility. They are used to dye hydroplastic fibres, for example polyester. The suspension is formed with the use of a dispersing agent and the dyeing is performed with a carrier, or at elevated temperatures (Groves et al, 1987).

Good wet-fastness is exhibited by reactive dyes, which form a covalent bond between the dye molecule and the fibre. They are water-soluble and anionic in nature. Commercial fibre reactive dyes have been developed for both wool and polyamide but the major success has been in the application to cotton and its blends. The use of reactive dyes is complicated by the hydrolysis of the reactive group of the dye in water, which can lead to the uptake of hydrolysed reactive dye. It is substantive during dyeing, but cannot react with the fibre and must be thoroughly washed out after dyeing, otherwise poor colour fastness to washing is obtained (Holme, 1991). There has been a significant growth in the use of reactive dyes for cellulosic fibres because of the ease of application compared with vat dyes. Reactive dyes produce bright colours and display good colour fastness.

Reactive dyes have however, been implicated in the increase in coloured effluent problems worldwide, due to their slow biodegradability. Fixation of reactive dyes during dyeing is incomplete and the unfixed portion, usually hydrolysates, is discharged in the effluent. The problem can be overcome according to Norman & Sneddon (1991a), either by ensuring complete removal of the hydrolysed dye, which results in more colour in the effluent, or by fixation of the hydrolysed dye. The latter is more effective and can be performed with the use of cationic polymers.

Comparisons between the amount of unfixed dye from several dye classes were made by Beckman & Sewekow (1991), which showed that basic dyes exhibit the least amount of unfixed dye, followed by acid, disperse, direct dyes and then reactive dyeings resulted in the largest amount of unfixed dyes being discharged in the wastewater. These results were confirmed by the dye manufacturer, Ciba-Geigy and Table 2.3 shows the results they obtained in Europe with respect to fixation rate, biological elimination and the percentage of dyestuffs in receiving waters, according to the class of dye (Richner, 1991).

TABLE 2.3 **Colour & Textile Effluents** (After Richner, 1991)			
DYE CLASS	**FIXATION RATE (%)**	**BIOLOGICAL ELIMINATION (%)**	**DYES IN RECEIVING WATERS (%)**
Reactive	50 - 80	30 - 50	10 -35
Azoic	70 - 80	30 - 60	8 - 20
Direct	70 - 80	40 - 60	8 - 18
Vat	70 - 80	50 - 80	5 - 15
Sulphur	70 - 80	60 - 90	4 - 15
Disperse	75 - 85	30 - 50	2 - 10
Metal Complex	85 - 95	40 - 60	2 - 10
Acid	85 - 95	40 - 60	2 - 10
Basic	85 - 95	60 - 90	1 - 6

The fixation rate and dye load in receiving waters will depend on the age of the factory and its machinery and the expertise and care taken by the dyers and machinery operators. In this country, the cost of water and effluent discharge are not sufficiently high to encourage people to use methods resulting in water and effluent savings.

The environmental problems of the textile industry arise due to the non-biodegradable nature of many dyes. They were specifically devised to be resistant to degradation in water or sunlight, so usually require a combination of treatment processes for decolourisation. This is costly and is often only resorted to once public pressure has been brought to bear to ensure compliance with standards that have not previously been enforced. Decolourized wastewater does not imply that the pollution load has been lessened. On splitting azo groups of certain dyes, hazardous, yet colourless by-products (aromatic amines) may be formed (Shaul et al, 1986).

The vast majority of textile products are coloured by dyeing and this can be performed using either continuous or batch processes. Certain products, such as knit fabrics, hosiery, and yarn are almost exclusively dyed using batch processes. Large amounts of carpet and some woven fabrics are also dyed in this way. It remains a popular method due to the flexibility, short-run capability and ease of control. Batch processes are generally inefficient in their usage of water and auxilliary chemicals (Bergenthal et al, 1985).

The amount of water used will vary according to the fibre, dye machine and process used. Auxiliary chemicals and dyes are added to the water and include exhaust and levelling agents; buffers and pH control chemicals; retarding, wetting & dispersing agents; carriers; softeners; lubricants and penetrants, among others. Following the addition of auxiliary chemicals and dyes, the dyebath liquor is heated to the required temperature and held until dyeing is complete and a level or even dyeing is achieved. The exhausted dyebath, now containing only a few percent of the original quantity of dyestuff, but still most of the auxilliaries, is dropped (emptied) and the dyed product is rinsed repeatedly with fresh water (Bergenthal et al, 1985).

The possibility exists of reusing the exhausted dyebath for subsequent dyeings and the auxiliaries can also be reused to reduce production costs. The volume of wastewater and amount of pollution produced is also limited by this method. To produce an effluent rich in chemicals and dyes, which is then discharged to sewer, is wasteful and expensive. Reducing effluent volumes and pollutant concentrations is therefore a cost effective option.

There is a new biotechnological approach to the production of textile dyes that may substantially alleviate the effluent problems associated with conventional chemical synthesis. The new dyes are produced from genetically engineered micro-organisms and are claimed to replace existing vat, mordant and disperse dyes, while introducing new opportunities relating both to the shades obtainable and to such properties as stability and fastness (Anon, 1989). These dyes are not in commercial use at this stage and have thus not yet been proven.

2.3 MEASUREMENT OF COLOUR

> *When paints or dyed cloth are to be sold, with the risk of legal disputes about conformity to specification, it is essential that the standards should be acceptible to all. As individuals differ in colour vision and in aesthetic opinions, the standardising institutions are led to measure stimuli, not sensations - to do physics, as being easier than psychology, although the ultimate purpose of colour is usually aesthetic* (Richardson, 1932).

The limit set by DWAF for the Umbilo Wastewater Treatment Works' effluent into the Umbilo River is 80 Hazen Units. The textile industry and treatment works use the American Dye Manufacturers' Institute (ADMI) method to measure colour in wastewater and thus the limit set by DWAF had to be converted into ADMI units for it to be relevant to the Committee (see Figure 3.1). To express the colour of industrial waste solutions or evaluate the effectiveness of waste colour reduction processes, it is necessary to specify the colour characteristics in definite values related to the colour sensations realized when viewing the wastes.

The American Dye Manufacturers' Institute (ADMI) is made up of all the major dye manufacturing companies. In 1970 it established an Ecological Committee to undertake studies of the effect of dyes on the environment. As a result of these studies, the ADMI Committee became aware of the need for a more reliable method for the measurement of colour of water.

The platinum-cobalt method defines the standard colour unit as that colour produced by dissolving potassium chloroplatinate and cobaltous chloride in distilled water (South African Bureau of Standards Method No. 198). The colour produced has a yellowish-brown hue and resembles that found in natural waters. For this reason, the ADMI developed a new method of analysing textile industry effluents for the presence of colour. This was required to apply to any hue, sensitive to small colour differences, related to APHA (American Public Health Association) values (also known as platinum-cobalt or Hazen Units) and require relatively inexpensive instrumentation (Allen et al, 1972).

Several methods for obtaining a measurement of the colour of water were considered by the ADMI Ecological Committee and rejected because of theoretical or practical limitations. It was considered important that the method devised be related to visual perceptibility rather than to concentration, since it is rare that the identity of the colourants responsible for the colour of water are known. It is even less common that a single colourant is responsible. Furthermore, it was the judgement of the committee that dyes posed a problem to the environmnent, only in terms of their aesthetic effect (Allen et al, 1972).

The ADMI method is based on the ICI (International Commission on Illumination) tristimulus value system. If two colours, A & B, are visually judged to differ from colourless to the same degree, the vector in the transformed colour space from colourless to colour A will be the same length as the vector from colourless to colour B. The length of these vectors being the single number uniform colour difference (Allen et al, 1972).

A person can match the effect of any colour stimulus by mixing light from three primary sources. The proportion of three primaries (red, green and violet) necessary to match a unit quantity of light at a single wavelength was determined. These proportions of the primaries are known as tristimulus values (Rudolfs & Hanlon, 1951). The ICI system of specifying colour based on these values has had wide acceptance in relating physical measurements and the stimuli perceived by the normal observer. This system was used to specify the colour of wastewater in terms of the dominant wavelength (hue), purity and luminosity.

It was determined that a solution which differs visually, regardless of hue, from colourless to the same degree that the yellow platinum cobalt 100 standard differs visually from colourless, should also have a value of 100 in ADMI units. It was found that a multiplier of about 1 400 was necessary to yield a colour difference value numerically equal to the APHA value. The multiplier will differ in value from instrument to instrument, according to Allen et al (1972). The methods employed to determine colour in Hazen units and platinum-cobalt units are identical. I was unable to determine why South Africa has preferred to adopt the name Hazen instead of platinum-cobalt units in water analysis and it appears to be merely tradition.

The colour of a sample measured in ADMI units is considered to be the colour of the light transmitted by the solution after removing the suspended material, including the pseudo-colloidal particles. It is recognised that the colour characteristics of some samples are affected by the reflection of light from suspended material present. However, **The Standard Methods for the Examination of Water and Wastewater** (Taras, et al, 1971) states that until a suitable method is available for making solution reflectance determinations, the colour measurements will be limited to the characteristics of light transmitted by clarified wastes.

Suspended materials in ADMI samples are removed by filtration through a standard filter aid medium. Centrifuging is not used as the results will vary with the size and speed of the equipment and particles with a specific gravity lower than that of water will tend to float or remain in suspension (Taras et al, 1971). The colour of the filtered sample is expressed in terms which describe the sensation realised when viewing the waste. The hue (such as, red or yellow) of the colour is designated by the dominant wavelength, the degree of brightness by the luminance and the saturation (such as, pale or pastel) by purity. These values are best determined from the light transmission characteristics of the filtered wastes by means of a spectrophotometer (Taras et al, 1971).

The clarification procedure may remove some dye from solution by adsorption when synthetic solutions of some dyestuffs are so treated. The limited evidence according to Taras et al (1971), Allen et al (1972) and Bratby (1980) indicates that this is not the case with the dye-bearing industrial wastes which were examined. However, this may not be so with all classes of dyes. Table 2.4 lists dyes used by the Pinetown textile industry, that were analysed for ADMI colour and which were not filtered or filtered once prior to analysis to determine the extent of colour removal on filtration.

These results have been tabulated to illustrate the trend that some colour is lost in filtration, especially with respect to reactive dyes. According to Shore (1991), a survey determined that reactive reds and sulphur blacks caused most of the difficulties in effluent treatment. The samples from Twistex were very viscous and extremely difficult to filter and in so doing, much colour was removed. Work is therefore required on the ADMI method to establish the best means of filtering out the suspended matter that would otherwise interfere with the colour analysis, yet not removing *colour-causing* compounds.

TABLE 2.4
The Effect of Filtration
on ADMI Values for Different Dye Classes

DYE	FILTRATION	ADMI	COLOUR REMOVAL (%)
composite	unfiltered	9 429	
	filtered x1	8 547	9,4
acid	unfiltered	43 329	
	filtered x1	41 915	3,3
reactive	unfiltered	113 928	
	filtered x1	105 343	7,6
disperse	unfiltered	15 632	
	filtered x1	14 576	6,8

A difficulty in measuring the colour of water is caused by the fact that the intensity of colour varies with pH. There is a concurrent pH effect on both the particle size and number of colour-producing particles. Increasing the pH, decreases the particle size and increases the particle numbers. Therefore, prior to measuring colour, the pH is adjusted according to that required for the particular method used. It must also be ensured that fresh samples are analysed, to prevent pH-related errors from being reported.

2.4 COLOUR QUANTIFICATION

The dyes used by the Pinetown textile industry are often proprietary in nature, so their chemical structures are not always available due to patent laws protecting them. The dyes are identified by their Colour Index (C.I.) names, but owing to the fact that most dyes are diluted with several additives to control their shade and strength, the structure of the dye would only represent a portion of the chemical makeup of the commercial colour.

2.4.1 Colour Balance

Two attempts were made to establish a colour balance over seven days for the Pinetown textile industry. This timespan was chosen to ensure that high and low peak levels of colour would be sampled, as weekends record both lower flows and colour levels. However both attempts (September 1991 and February, 1992) were ineffective due to a lack of committment by some of the parties involved, the lack of resources allocated to the project and eventually, the lack of time available. The latest attempt (1992) was ineffective, due to the decrease in production in the factories, as the colour load was not representative of the industry.

The final results obtained were inconclusive and therefore only used to derive as much information concerning colour in dyebaths, effluent and the Works as possible. In order for any colour balance to succeed, strict co-ordination of the sampling is required to ensure that the results obtained are from the same time span and that all the samples required are in fact obtained. For this, samplers would be required for each factory (including nightshift and weekends) and analysts needed to prepare the samples and obtain the ADMI values.

Information from the data collected from individual dyebaths gave some insight as to where the most effective form of treatment could occur. If the reactive red and sulphur black dyebaths alone were to be decolourised, as Shore (1991) suggests, then the following graphs give some useful insights as to where most of the colour is contained.

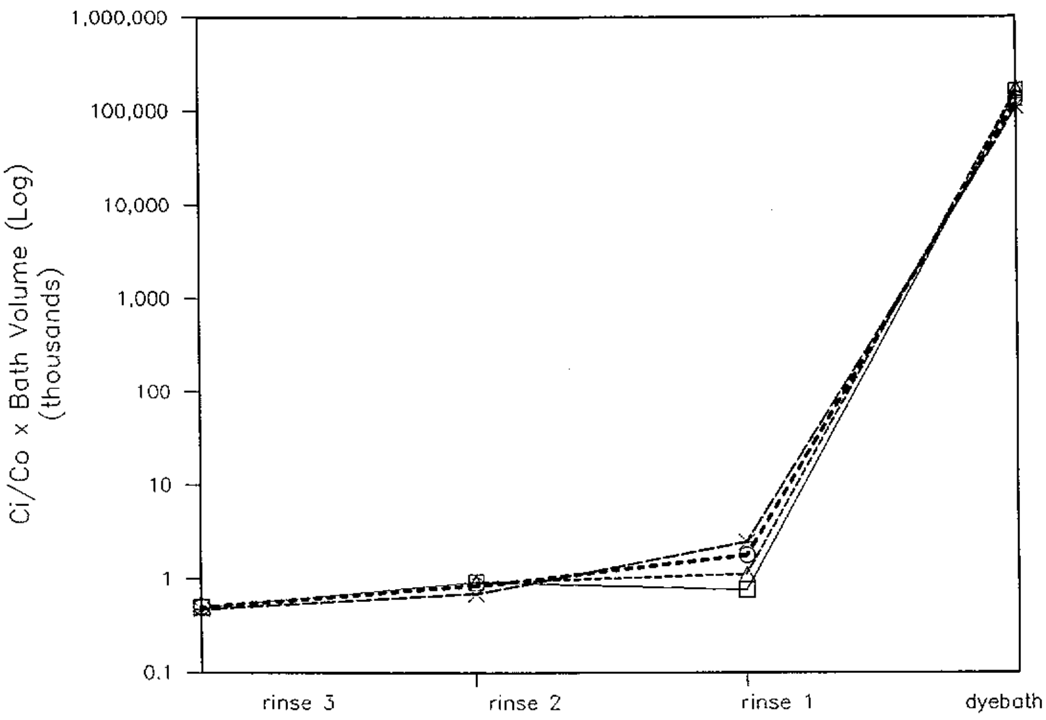

FIGURE 2.2: CUMULATIVE COLOUR
Dyebath & Rinses

Cumulative colour (Ci/Co x Dyebath volume) is shown in the graph in Figure 2.2, with Ci representing the concentration of the sample and Co, that of the dyebath. The graph provides an insight into the relative concentrations of colour, when comparing the dyebath with successive rinses. The scale is logarithmic on the Y-axis and it shows that if the dyebath were solely considered for decolourisation, most of the colour would be removed from the effluent, with the rinses containing relatively little colour.

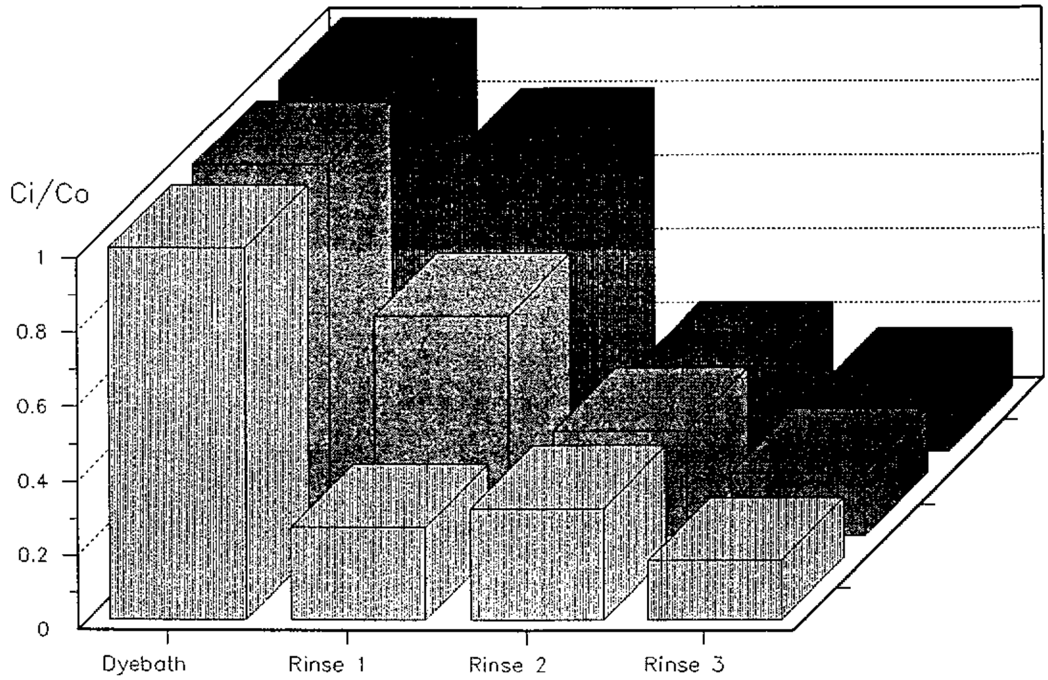

FIGURE 2.3: TOTAL COLOUR CONCENTRATION
Dyebath & Rinses

The bar diagram in Figure 2.3 details relative colour of three rinses, when compared with dyebaths of three different samples. It shows that the first rinse may often contain a significant amount of colour and as a precautionary measure, the dyebath and the first rinse should be considered for decolourisation to ensure the most effective removal of colour. An increase in colour of the rinsewater can be seen between rinse 1 and 2 of one of the samples and this was due to an acid wash of the fabric to ensure complete removal of dye, which increases fastness of the material.

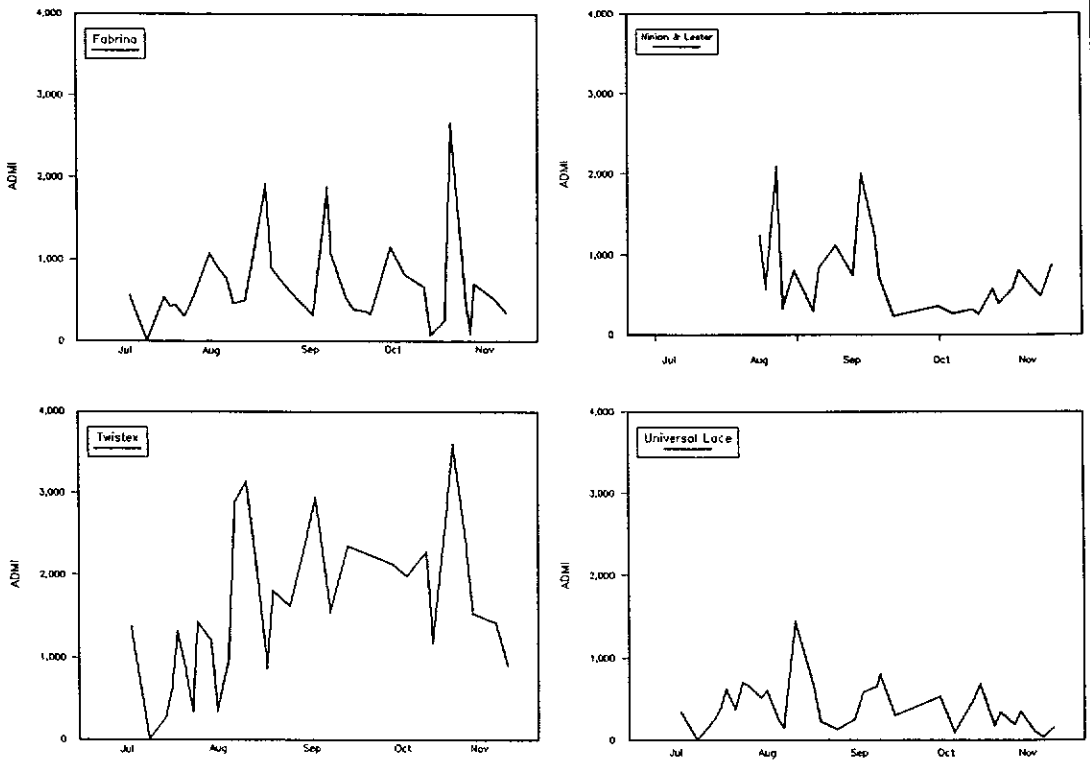

FIGURE 2.4: PINETOWN TEXTILE INDUSTRY ADMI, 1990

The graphs in Figure 2.4 show the variations in ADMI in factory samples over the year (1990) and the data was obtained from the Works' weekly sample results. Both Ninian & Lester and Fabrina's samples show many peaks of colour and by treating the darker hued dyebaths and the first rinses, these peaks should be sufficiently reduced. Universal Lace does not contribute a significant amount of colour to the Works, however, when black fabric is dyed, acid black is used, which has been shown to pass through biological processes untreated (Shaul et al, 1991 in Table 2.6). This should therefore be considered for replacement by a less refractory alternative, if a suitable one exists.

The ADMI of Twistex's samples fluctuates the most and would result in colour peaks at the sewage works. At present their effluent tank discharges continuously and if the wastewater were allowed to equalise, it would reduce the peaks in flow and colour. Twistex prints and dyes carpet yarns and uses thickeners in the process. The suggested methods for decolourisation by the consultants were not effective due to this viscosity and dilution must precede any form of treatment.

2.4.2 The Works

The raw sewage and wastewater entering the Works is screened to remove solids and then passes through a grit channel. This causes the flow rate to decrease which results in grit and other large solids settling out. The effluent stream then splits and enters one of six primary clarifiers, as shown in Figure 2.5, which are circular settling tanks. Effluent enters through the centre of the tanks, flows under a retaining wall (to collect scum) and the liquid then flows over a weir. The sludge, which settles at the bottom of the clarifier, is regularly removed and anaerobically digested.

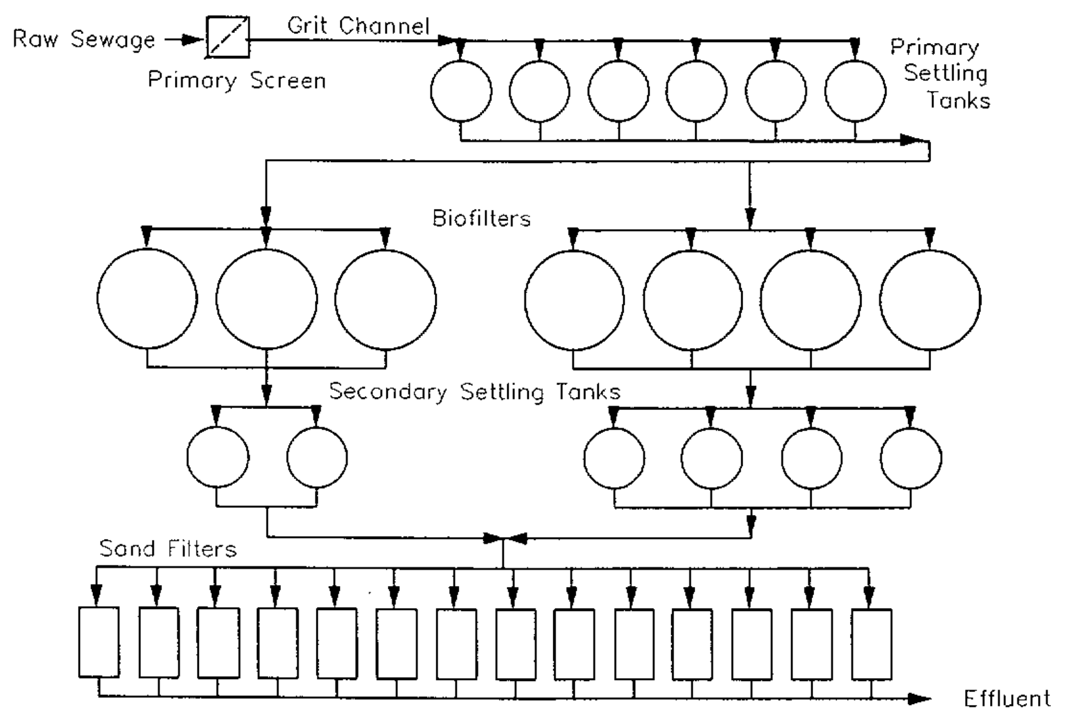

FIGURE 2.5: THE WORKS - PROCESS FLOW DIAGRAM (After Barnett, 1991)

The effluent flow splits into two after the clarifiers and trickles into one of seven biofilters from a rotating manifold. The term *filter* is a misnomer and originates from the early days of land treatment when it was assumed that mechanical filtration of sewage occurred in the soil (Murray, 1987). The trickling filter process uses a large number of contact surfaces upon which micro-organisms grow and which are sustained by the nutrients in the sewage.

The environment is aerobic and is used to transform poor quality effluent. It provides a reliable and simple method for wastewater treatment and comprises a bed of media, in this case crushed stone, over which settled effluent is sprayed. Slime containing a large number of organisms forms on the surface of the media, over which the effluent percolates. As it flows over the slime, a series of complex aerobic biochemical reactions takes place and organic material is thereby removed from the wastewater. The slime increases in thickness and eventually portions slough off and are removed with the effluent. This slime is known as humus and is separated from the wastewater by sedimentation in the secondary settling tanks.

In an established filter, it takes approximately half an hour for the sewage to trickle over the stones from top to bottom (Technikon RSA, 1989). This does not mean that all of the impurities in the sewage are purified in this time and although the liquid passes quickly through the bed, the humus that is washed off the stones has been in the filter for much longer. Barnett (1991) ascertained the mean residence time of the Works' trickling filters using tracer dye, to be 32,2 minutes, which compares favourably with that obtained in the literature. It was noticed however, that the flow is not spread evenly across the filter. The effluent percolating close to the walls was seen to pass through the bed unimpeded.

Sedimentation is performed in one of four secondary clarifiers, which are similar to the primaries. The effluent leaving these tanks converges and is sprayed with a fine mist of water to induce foaming. This tendency can be destroyed by microbial action as most modern detergent formulations are at least partially degradable (Jones, 1973) and the scum, which is regularly removed, acts as a flotation medium. The wastewater then passes through one of fourteen sand filters, prior to chlorination and discharge to the Umbilo River. It is this effluent that is often highly coloured and has the propensity to foam.

The sludges removed during treatment are digested anaerobically and then dried. Anaerobic digestion has been suggested as a means of degrading concentrated dye effluents, especially those resistant to aerobic processes (Porter & Snider (1976). It has also been suggested that disperse azo dyes may undergo reduction on the bottom sediments in the aquatic environment, resulting in the subsequent release of potentially hazardous aromatic amines into the water column (Weber, 1988). This would have to be investigated, to ensure that harmful by-products are not introduced to the digestion system, if it is considered as a decolourising technique.

The Works is currently commissioning an activated sludge process, for treatment of half the influent. This may improve decolourisation of the effluent slightly, by adsorbtion of some dyes on the sludge. When inert dyes are present in a waste stream, they may be removed by adsorbtion on mixed liquor suspended solids if the concentration is high and the retention time is long enough to allow for adsorbtion. If the time span is too short however, or the dyes are pigments, they may pass through the waste stream unaffected (Porter & Snider, 1976).

The ADMI method of colour analysis requires further research to ascertain the effects of filtration and pH on dyes used by the Pinetown textile industry. A colour balance will reveal the sources of most of the colour and verify the information obtained on colour loads, with respect to time. If highly coloured effluents are discharged at periods of peak flow into the Works, dilution would reduce most of the colour problem. The ADMI limit could then be established for the effluent leaving the Works and thus determined for the coloured wastewaters leaving the textile mills.

2.5 TREATMENT OF COLOUR

The textile industry transforms natural and synthetic fibres into fabrics, by processing fibres to form yarns, which are then woven, knitted or otherwise processed to create fabrics and these are then dyed, printed and/or finished. The process of finishing involves the treatment of a fabric that modifies its physical or chemical properties. This may include, for example, fire retardation, which reduces the flammability of textile fabrics and the introduction of soil release materials to aid in the removal of dirt and oil-borne stains. Most of these processes use chemicals that are resistant to biological treatment (Jones, 1973).

The rapidly increasing usage of synthetic dyes, new techniques and progressive technology in the finishing stages of textile production is directly responsible for the need to find new and efficient methods for the decolourisation of effluents. The traditional methods only achieve partial removal of organic matter and the most widely used methods of effluent purification are biochemical, however, the majority of dyes in current industrial use are only very slowly oxidised in biological plants. Subsequently their coloured effluents harm aquatic environments by upsetting the oxygen balance, retarding photosynthesis and suppressing natural purification (Shendrik et al, 1989).

Although mixing textile wastewaters with domestic wastes has led to successful treatment in the past, the increasing inertness of the effluents has rendered this approach less efficient. A research committee of the American Association of Textile Chemists and Colourists compiled a list of textile chemicals and determined the results of the five day biological oxygen demand (BOD_5) test for each. Out of 300 products, almost 40 %

had less than 10 % BOD_5 by weight of chemical and were therefore relatively resistant to biodegradation (Committee RA58, 1966). Textile chemicals usually require longer retention times in biological processes, which is often not feasible due to the constraints on space.

Wastewater treatment works dealing with textile effluents need flexibility to deal with the changing constituents, which arise due to changes in fashions and therefore fibres, chemicals, dyes and processes used. This is often difficult to achieve in a municipal treatment works and raises the question of whether textile wastewaters should be treated by the Works or on-site, at the factories.

The auxiliary chemicals used in aqueous dyeing may also present a problem to biological processes. Carriers, for example, are used to accelerate the dyeing process and are usually discharged to sewer on completion of the operation. They are relatively inert, but may be adsorbed onto sludge and if this is not handled correctly prior to ultimate disposal, may pose further hazards in landfill leachate.

Waste disposal in South Africa is currently under review and the *duty of care* principle is likely to be adopted in guiding legislation. This will shift the responsibility and liability for waste to the producer. Landfill, as an ultimate form of disposal for wastes, will no longer be cheap and some form of pre-treatment will probably be required before disposal of textile wastes will be considered in future.

Due to variations in textile effluents from process to process and even from hour to hour, it is necessary to have some preliminary treatment on site. An equalisation tank, for example, will prevent peaks in discharge in terms of volume, colour and other characteristics, which is essential to prevent shock loading of the treatment facility. When on-site treatment methods are able to recover expensive chemicals from waste streams, these savings may fund new production processes that would have previously been considered too expensive. Thus, pollution prevention should not only be viewed as a financial liability, but an opportunity to reduce costs.

Although many textile mills have similar operations, the type and concentration of pollutant in the effluent stream and its flow rate varies from plant to plant. It is therefore difficult to design a waste treatment process that would handle all types of textile wastewaters. In many cases, more than one unit process will be necessary to satisfy water quality standards (Rhys, 1978).

A wide variety of treatment methods is presently available to treat liquid discharges from textile mills. In addition to conventional biological treatment processes, adsorption, precipitation, membrane processes, oxidation and flotation have been found to be effective, according to the particular situation. To solve the pollution problem created by a particular mill, an initial step to accurately characterise the effluents is essential.

2.5.1 Biological

Dyes are considered recalcitrant to biodegradation, as most are developed to be resistant to oxidation. A garment saturated with water or perspiration and well inoculated with micro-organisms is an excellent culture medium and only compounds resistant to biochemical or oxidative degradation under these conditions will be fast and thus acceptable as a stable dye.

The biological wastewater treatment process is complex and sensitive to pH, temperature loading and the presence of many chemicals. When oxygen combines with partially degradable organic materials in an aerobic process, it does so according to the following equation (after Porter & Snider, 1976):

$$organics + O_2 + nutrients \rightarrow new\ biomass + CO_2 + non\text{-}reactive\ ingredients$$

The quantity of new biomass produced will depend on the ease of degradation of the organics in the waste and the retention time employed. Long retention times produce less biomass as some of the sludge is destroyed by endogenous respiration.

In the late 1950's, research studies of colour removal from textile effluent streams were conducted. Trickling filters and activated sludge plants were able to remove 84 and 93 % of colour respectively and chemical coagulation of cotton dye wastes resulted in 80-91 % removal of colour (Jones, 1973). However, with the increase in the use and variety of reactive dyes, investigations show a reduction in purification efficiency and thus the colour problem associated with treated textile effluents has developed.

Studies of the biochemical oxidation of dyes and sulphides of textile mill wastewaters in aeration tanks showed that the activated sludge process decreased the concentration of organics and colour appreciably (Kogan et al, 1986). Development of filamentous sulphur bacteria, however, resulted in impairment of the sedimentation properties of the activated sludge in the aeration tank, resulting in a low sludge concentration in the system.

Some dyes may exert a toxic or inhibitory effect on biomass, requiring an acclimation period to stabilize the plant. Bacterial cultures selected for their degradative properties, may be specifically grown to seed the biomass. This is known as bioaugmentation and is of value in quickly acclimatising a biomass to recalcitrant wastewaters (Straley, 1984). It offers the increased flexibility of working directly with the bacterial biomass and allows flexibility in dealing with problems of acclimation, toxicity and restart.

These problems are particularly prevalent in the treatment of effluents from textile finishing and dyeing processes due to the batch and semi-batch nature of the industry. Azo-dyes decolourize under anoxic and anaerobic conditions and substantial selection among bacterial strains was necessary to find active cultures for bioaugmentation. These may help to provide the variability necessary for the natural selection which will allow the activated sludge process to biodegrade these and other toxic dyes (Straley, 1984).

The primary route through which dyes are removed from wastewater in the activated sludge process (ASP) is by adsorption on floc. Straley (1984) reported the fate of dyes in ASP and a summary is provided in the following table.

TABLE 2.5
Activated Sludge Process
Adsorption Results for Different Dyestuffs
(After Straley, 1984)

DYE TYPE	ASP ADSORPTION
Acid	Higher water solubility leads to less adsorption
Reactive	Poorly sorbed
Direct	Good adsorption
Disperse	Good-to-fair adsorption

As can be seen, the reactive dyes are not adequately removed by ASP and thus the newly commissioned process at the Works for half the influent, will not remedy the colour problem experienced. The elimination of dyes in ASP treatment results in its adsorption on sludge and the rate is not always high, thus most plants use a combination of ASP for various organic substances and coagulation or dissolved air flotation for the dyes.

In the study by Shaul et al (1991), eleven of the eighteen azo dyes studied passed through the ASP substantially untreated. Four compounds were adsorbed onto the waste activated sludge and apparently not biodegraded. Three compounds appeared to biodegrade according to the results obtained which are summarised in the following table. Some of these dyes are used by the Pinetown textile industry. The azo dyes have been highlighted by the EPA for further toxicity testing, due to their (or their by-products) carcinogenicity.

TABLE 2.6
The Fate of Dyes in the Activated Sludge Process
(After Shaul et al, 1991)

UNTREATED DYES	UNTREATED AND ADSORBED	BIODEGRADED
C.I. Acid Black 1	C.I. Acid Blue 113	C.I. Acid Orange 7
C.I. Acid Orange 10	C.I. Acid Red 151	C.I. Acid Orange 8
C.I. Acid Red 1	C.I. Direct Violet 9	C.I. Acid Red 88
C.I. Acid Red 14	C.I. Direct Yellow 28	
C.I. Acid Red 18		
C.I. Acid Red 337		
C.I. Acid Yellow 17		
C.I. Acid Yellow 23		
C.I. Acid Yellow 49		
C.I. Acid Yellow 151		
C.I. Direct Yellow 4		

The dyes appearing in the left-hand column (untreated) require detailed analysis to determine any impact they may have on the Works and the aquatic ecosystem of the Umbilo River, into which they are ultimately discharged.

According to the results obtained by Porter & Snider (1976), no significant colour loss (optical density) was observed after the 30 day BOD test on certain dyestuffs. The disperse and vat dyes are pigment dispersions rather than true solutions and showed an average colour loss of 15 % after 30 days in the incubated BOD bottle. The authors conclude that this was as a result of the settling of the dispersed pigment on the bottom of the bottle, rather than degradation. As no visible colour change occurred with any of the dyes in the Porter & Snider (1976) experiments, there is little likelihood that molecular changes took place. The small changes observed with the vat or disperse dyes, may be partially as a result of changes in the dispersion particle size, which could change the optical density of the solution. The authors conclude that it is possible that many of the dyes they tested may degrade under anaerobic conditions (Porter & Snider, 1976). This treatment option requires further investigation for the Pinetown situation.

Ogawa and Yatome (1990) used wastewater clarification technology for removing dyes and other organic substances in a single operation by the use of dye assimilating bacteria. The micro-organisms were isolated from the drainage ditch of a dyeing plant and the degradation pathways were identified. p-Aminoazobenzene and acid azo-dyes in the model wastewater were effectively degraded by the continuous submerged culture of the micro-organisms and the dye-degradation activity was determined to be stable for a long time (Ogawa & Yatome, 1990).

Weeter and Hodgson (1978) found that unconditioned sludge did not reduce colour as well as acclimated sludge. The dyes used did not exhibit sufficient biodegradable properties or colour removal via biosorbtion to justify discharge to a biological treatment process, according to the authors. The conclusion common to most research in this field reiterates that each waste demands a tailored solution requiring a combination of methods.

Eighty-seven dyestuffs have been tested by Pagga & Brown (1986) in short-term aerobic biodegradation tests. The results confirmed that they are most unlikely to show any significant biodegradation in such tests. With many, a substantial colour removal was observed which may be attributed to the elimination of the dyes by adsorbtion. In some cases, dissolved organic carbon (DOC) removal did not correlate with colour removal and may be due to the presence of non-coloured organic components in the dyestuff.

The influence of basic dyes on the growth rate and nucleic acid content of Bacillus subtilis cells was investigated to elucidate inhibitive reactions in the biological treatment of waste dye-liquor (Ogawa et al, 1988). This species of bacterium grows in activated sludge and both the mean growth rate of the cell population at the logarithmic phase and the cell concentration at the stationary phase decreased with the addition of the dyes. Purification at many factories is carried out continuously under conditions that the micro-organisms growing at the logarithmic phase exist abundantly in the treatment tank. The physiological activity of the cells was however, noted to be partially restored by acclimation. The triphenylmethane dyes tested, strongly inhibited cell growth, which verifies other toxicity results obtained for these dyes (Michaels & Lewis, 1985; Brown & Anlicker, 1988).

Basic dyestuffs that are most likely to be toxic, are in general very substantive to the substrate which they are dyeing and are also well removed in biological treatment processes. The likely environmental fate of dyestuffs is by sorbtion, either onto sewage sludges or sediments of natural waters. The azo dyes, in particular, will be degraded in an anaerobic environment, according to Brown and Anliker (1988) and the amines produced as the anaerobic metabolic products will themselves be degradable or essentially non-toxic to aquatic life. Any amine formed by azo scission is likely to be biodegraded more quickly than the rate of scission and so should not accumulate in the aquatic environment, according to these authors. However, other researchers continue to analyse azo dyes and their degradative by-products in toxicity tests, due to conflicting results, as reflected in the work of Shaul et al, (1991).

These authors are concerned by azo dyes, because some of the dyes, dye precursors and/or their degradation products (for example aromatic amines) have been shown to be, or suspected to be, carcinogenic. Studies also suggest that disperse azo-dyes may undergo reduction in bottom sediments in the environment, resulting in the subsequent release of potentially hazardous aromatic amines into the water column (Shaul et al, 1991).

The diversity of opinions with respect to the fate and toxicity of azo dyes highlights the fact that broad assumptions about dyes cannot be made at the level of dye classes. Individual dyes and their dyeing circumstances have to be investigated and only then can relevant conclusions be made as to whether or not the dye is going to have an effect on health, treatment process or the aquatic environment. This underlines the need for removing the secrecy with which the dye manufacturers retain toxicity information in South Africa, for the benefit of all involved in the Committee's work.

An attempt was made to treat textile wastewaters by growing vascular aquatic plant (Water Hyacinth) in the effluent after partial biological treatment. The results were encouraging and the plants, besides effectively treating the waste, yielded a considerable quantity of biogas (Kulkarni et al, 1982). Prehydrolysate liquor obtained from a rayon pulp mill was used as a substrate to produce single cell protein (SCP). In a laboratory study, Bajpai & Bajpai (1987) determined that substrate utilisation by the micro-organisms resulted in a 70 % reduction in the BOD of the prehydrolysate. Bioconversion of prehydrolysate would not only solve the pollution problem, but could also yield useful products to feed our hungry population beset by drought and failing crops.

Most wastewater treatment plants depend on biological respiration for sludge generation and ultimate removal of organic contaminants from the waste stream. Porter & Snider (1976) claim that a particular textile chemical need not be biodegradable to be removed by biological treatment. It may be insoluble and thus removed directly by settling, or it may be adsorbed by the biosludge and removed when the sludge is separated. If the latter applies, sufficient sludge must be generated to adsorb the chemical. Subsequent studies on dyes exposed to sludges, suggest that all the dyes tested are strongly adsorbed and tenaciously held by wastewater treatment plant sludge (Tincher & Dickson, 1988).

Coagulation-sedimentation of wastewater from a textile mill using different coagulants was carried out by Abo-Elela et al (1988). The use of lime-ferrous sulphate reduced the organic load considerably. As an alternative, biological treatment of industrial wastewater combined with equal proportions of domestic sewage using a complete mixing ASP produced a very high quality effluent. A final process design was developed and economic evaluation of the methods adopted indicated that the costs of chemical treatment are far less than those of biological treatment.

2.5.2 Chemical

In biological effluent treatment plants, hydrolysed reactive dyes are neither degraded nor adsorbed by the activated sludge process to a sufficient degree, thus a separate purification operation becomes necessary to remove them. According to Schulz et al (1988), a cost-effective possibility is the precipitation/flocculation reactions of high-load partial currents with cationic flocculants.

Despite optimally selected conditions for the precipitation/flocculation reaction and separation of the flocculates formed, residues of the flocculants used still remain in the decolourised wastewater. Schulz et al (1990) conclude that no negative effects on the degradative performance of the activated sludge plant was observed. It is quite common to treat the wastewaters from dyeing and finishing plants with coagulants. However, disposal of the resulting precipitates (sludges) remains an important problem, in view of the subsequently hazardous nature of the leachates produced in the landfill.

Ozonation can attain high levels of colour removal, reduce the level of soluble organics, improve biodegradability, destroy phenols and ensure disinfection (Beszedits, 1975) and is particularly effective as a polishing step after more conventional treatment methods. One of the drawbacks is cost, however, improvements in ozone generators and contacting equipment along with increasingly stringent environmental regulations will undoubtedly lead to a more widespread application of ozone.

Gerber (1982) illustrated the behaviour of an effluent which contains dissolved dyestuffs in response to ozone exposure. Initially the dyestuff concentration decreased very rapidly in proportion to the amount of ozone, but then the rate flattened out as competitive reactions of ozone with other substances and reaction products took place.

Azo dyes have a tendency to be easily decomposed by ozone and this is markedly accelerated when ozonation is accompanied by ultra violet radiation (Matsui et al, 1984). This treatment has potential as a means of decolourising exhaust dyebaths for re-use and a dose of 200 mg/M ozone was found to remove more than 95 % of the colour present (Shore, 1991). Bondar et al (1983) concluded that it is feasible to ozonise the most coloured part of wastewater from the dyeing-finishing process at textile plants, before it is mixed with the remaining volume of general plant wastewater.

Ghosh et al (1978) attempted to remove colour by chlorinating the effluent from an aeration tank. There was a slight shift in the absorbtion spectrum, indicating a change in hue, but only partial oxidation of the dyestuff was achieved at extremely high dosages of chlorine (>70 mg/M). The Works chlorinates the final effluent prior to discharge, but little or no decolourisation occurs, as can be seen in the graph in Fig. 3.7.

2.5.3 Physical

The application of biological methods to changing dye-house effluents has often been found to be inadequate and has resulted in more stringent effluent criteria set by the treatment facilities for receiving textile wastewaters. Several advanced techniques have been proposed as alternatives to conventional treatment processes. Adsorbtion with activated carbon, which requires approximately one-seventh of the land required for a biological process, produces no secondary sludge and is capable of treating highly toxic wastes, is thus an attractive option (Volesky & Roy, 1979).

This adsorption involves the attachment of the coloured material onto a substrate and is the term used to describe the existence of a higher concentration of any particular substance at the surface of a liquid or solid, than is present in the bulk of the medium (Glasstone & Lewis, 1976). When dealing with solids, a distinction can be made between absorption and adsorption. The latter involves an excess in concentration at the substrate surface, but absorbtion implies there is an uniform penetration by the solid of a given substrate. Although a large surface area is important in determining the adsorptive properties of a given material, the extent and firmness of adsorption are dependent to a great extent on the nature of the adsorbent and the substance that is adsorbed (Glasstone & Lewis, 1976).

Activated carbon is treated, resulting in an increase its adsorptive power, but requires regeneration to clean the surfaces. This and the initial raw materials, makes the process an expensive option in the decolourisation of wastewaters. Carbon treatment is rarely sufficient to treat dye wastes in a single stage and when suspended materials such as solids, dispersed dyes and lint are present, additional physical and chemical treatment steps are required (Rhys, 1978).

Solvent-based processing has been suggested as an alternative to the use of water in certain industries using large volumes of water. This idea was presented as an option for the textile industry in South Africa by Veldsman (1970). He stated that it would be unlikely that water would become completely eliminated, but that it would reduce water consumption. In South Africa, especially for the textile industry located in the drought-stricken Eastern Cape, this could be considered a viable option.

2.5.4 Operating Plants

One of Europe's largest industrial sewage treatment plants was commissioned for the Grenzach Works of Ciba-Geigy AG, Basel, where dyestuffs, textile auxilliaries and industrial chemicals are produced (Anon, 1976). This plant treats the highly contaminated industrial sewage and incinerates the process sludge and the work's industrial waste, together with the municipal sludge.

More than half the US carpet production occurs around the city of Dalton, Georgia, where industrial and domestic wastewaters are mixed and treated in a joint treatment plant. The processes include primary settling tanks, high rate trickling filters, activated sludge with extended aeration and final clarification. The sludge is thickened by dissolved air flotation and then digested anaerobically. The colour of the final effluent, was approximately 30% less than that of the incoming wastewater (Duchon & Painter, 1978).

Turner (1978) provided a cost-effective treatment alternative by using flocculation and dissolved air flotation to produce an on-site effluent which was light pink in colour. Samples of white, untreated cloth were immersed in this wastewater and no residual colour was absorbed by the fabric. This proved that the effluent was acceptable for recycling and effluent discharge costs decreased by more than 11 pence/m^3.

The East Burlington wastewater treatment plant was upgraded to deal with effluent with average platinum-cobalt colour units as high as 1000 (Kornegay, 1990). A powdered activated sludge treatment (PACT) system and wet-air regeneration unit was installed, where the PACT system follows treatment in an aerated equalisation basin and primary treatment, and involves the addition of PAC to the aeration chambers of the activated sludge system. In effect, physical and biological treatment take place simultaneously, successfully removing colour, biodegradables and non-biodegradables in a single stage.

The Southern Sewage Works receives most of Durban's textile effluent. Mondi has an agreement with the Works to use the treated effluent in the manufacture of paper and pulp, however, the colour in the effluent emanating from the textile industry has caused problems for Mondi's processes. The water is decolourised by passing it through activated carbon, but if it is highly coloured, this treatment is not always effective. Regenerating carbon is expensive and not completely efficient, as successively less capacity for adsorbtion is acheived after each regeneration.

The Southern Works thus has to ensure that the textile industry does not discharge their effluent in peaks of colour and volume. The effluent should ideally be stored in the textile plant's holding tank and pumped out regularly after equalisation, to ensure a more dilute colour concentration and even flow. The Work's wastewater not used by Mondi, is discharged via the ocean outfall, and has generated few complaints. The Durban City Engineers' Department has also convened a Colour Removal Committee, which includes Mondi, to try to alleviate their colour problems and is interested in the direction the Committee's work is taking.

2.6 CONCLUSION

Colour is a subjective sensation and at wavelengths coinciding with the perception of red, less dye is needed to reach the threshold value, than for violet or blue. This explains why more complaints are received when the Umbilo River is coloured red.

Rivers may be naturally coloured and in a healthy state, but require decolourisation if used for potable purposes, for aesthetic reasons or for health reasons, if chlorinated. Coloured effluents from the textile and paper & pulp industries also colour the watercourses into which they are discharged, often after intense treatment. These discolourations have attracted adverse publicity for the companies involved and require costly ameliorative solutions.

Dyes and the practice of dyeing have formed an integral part of the history of civilisations and the present day is no exception. Modern dyes have however, been developed to be resistant to biodegradation and thus refractive in biological treatment facilities. Dyes can be classified according to their application and the classes include basic, acid, direct, sulphur, azoic, vat, disperse and reactive dyes. The latter class have been implicated in the increase in problems associated with coloured effluent discharged from treatment facilities.

Some dyestuffs have been determined to be hazardous and the risks involved are forming the basis of ongoing investigations. Dyes may be hazardous by affecting the micro-organisms at the treatment works, or on discharge to a watercourse, may have a negative impact on the aquatic environment. However, the hazard may not manifest itself in the dyestuff alone, but in the cocktail of chemicals and the processes in which it is involved.

Treatment facilities have been designed to cope with coloured effluents, but the treatment involved is specific to the situation. The successful operations usually involve a combination of biological and physico-chemical treatments, which are able to cope with the varying consitituents of the textile industries' effluents.

The Works' processes rely on biological treatment to reduce colour loads and this is not effective for removal of all dyes. It would be more practical to consider colour removal at source, rather than increasing the treatment options at the Works.

CHAPTER
THREE

LEGISLATION: COLOUR AND THE TEXTILE INDUSTRY

3.1 BACKGROUND

In the present climate of increasing environmental standards, industry is faced with the challenge of cleaning up its discharges to the environment. According to MacDonald (1991), this is the most dominant issue that industry has had to face since the energy crisis of the Seventies. Unlike the energy problem, it will not disappear in the wake of plunging crude oil prices. Both water treatment and process industries are coming under increasing pressure to significantly reduce the levels of toxic chemicals and oxygen-consuming wastes discharged to watercourses.

Strict national environmental regulations are not an inevitable hindrance to competitive advantage against foreign rivals. Tough standards can trigger innovation and upgrading, however, turning environmental concern into competitive advantage demands that the right kind of regulations are established. Pollution prevention rather than mere abatement or clean-up must be stressed (Porter, 1991).

The strong *green* lobby that has evolved in recent years in developed countries has led to actual and proposed legislation on environmental pollution, causing problems for the textile industry. Legislators take into account the toxicity of chemicals, but are also swayed by appearance. The problem with legislation according to Hazel (1991), is that legislators and civil servants advising them have little experience of industry and do not work on realistic time scales.

A case in the UK highlighted this problem, when Her Majesty's Inspectorate of Pollution introduced a zero limit for pentachlorophenol (PCP) in trade effluent. PCP is used by textile manufacturers in some countries, such as India, for preservation of grey cloth, which is then exported. The UK industry using this cloth, was advised to treat the ensuing effluent, for PCP's at source and that suitable techniques were available. However, the technology was not applicable as other chemicals present in the effluent would render the treatment ineffective. Hazel (1991) claims that the Inspectorate has little practical experience and that partnership with industry was not considered to solve the problems. The approach taken in the Pinetown situation involves consultation between industry and the authorities and therefore appears to have a better chance of succeeding in resolving the issue of colour in the Umbilo River, however, public participation was not considered and this may yet prove a stumbling block.

In order for the textile industry to survive, it is necessary that its suppliers do not offer products that cause pollution problems. Coloured effluent is easier to treat at source, where the waste stream is concentrated and uncontaminated, thus it would be more appropriate to establish a treatment process at the dyebath, than at the Works where the effluent is mixed and diluted. The dye and chemical manufacturers should also be included in the Committee, to ensure that international pollution prevention initiatives are made available and to ensure that the responsibility for solving the problem, not only lies with the textile companies, but those that manufacture and supply the chemicals implicated. This is in keeping with the duty of care philosophy that is guiding new environmental legislation in South Africa.

Although scientists and engineers have been working with the problems of water pollution control for nearly a century, public interest was negligable until recently. In the developed world, standards of living have increased and there has been a corresponding shift in emphasis on needs. The issues of food and shelter have been addressed for many people and their attention has focused on the need for a healthy environment. South Africa cannot be considered a developed country, despite the emergence of vocal, environmentally concerned citizens, as they are a minority group, usually from a privileged section of the population. However, their concerns cannot be ignored and aspects of environmental degradation, especially the greenhouse effect and depletion of the ozone layer, have generated public concern and antagonism toward development in general, and industry in particular. The perceptions of these people need to be accomodated, as they are also consumers of the products of the textile industry. However, their concerns are not necessarily shared by the majority of South Africans.

Khan (1991) claims that it stands to reason that someone living in a squatter camp using a bucket toilet cannot be bothered about beaches spoiled by the spillage of raw sewage into the sea. White people in South Africa tend to associate water with leisure pusuits, but black people associate it with survival, according to the findings of the Natal Town and Regional Planning Commission survey in 1987 (in Khan, 1991). Cynicism arises when white people agitate to protect fragile ecosystems from black squatter settlements, yet seem powerless to prevent the construction of upmarket housing estates. It is difficult for black people not to wonder whether environmental concern might be used as a smokescreen for racist motives.

The South African economy is beset with the problems of low growth and high inflation rates. These place severe economic pressures on the economy and create a climate not conducive to increased expenditure on pollution prevention and control. The implementation of sanctions resulted in a shortage of foreign capital and isolation from new technologies, both of which have impacted unfavourably on future development and environmental control (Breyer-Menke & Moffatt, 1990).

The fundamental need in environmental management lies in maintaining a balance between environmental protection and economic development. South Africa needs development in order to survive the uncertain political future, however, this cannot be free of pollution. An equilibrium needs to be established and steps taken to ensure that the balance is maintained. This requires effective legislation and consultation at all levels, including industry (workers and management), regulating authorities and the public.

3.2 THE UNITED STATES OF AMERICA (USA)

The USA Environmental Protection Agency (EPA) has conducted an active and unique program with the textile industry to develop workable and effective water pollution regulations. This resulted in the establishment of textile effluent limitation guidelines and standards in 1974 (EPA Textile Effluent Regulations, July, 1974). The regulations covered the spectrum of effluent limitations for existing sources, performance standards for new sources and proposed pre-treatment standards for discharges to publicly owned treatment works (Gallup, 1976). The textile industry with its seven sub-categories is one of sixty-four industrial categories containing nearly four hundred sub-categories covered by effluent regulations. These are required under several sections of the Water Pollution Control Act Amendments of 1972.

An analysis of the economic impacts of the 1972 Federal Water Pollution Control Act Amendments on the textile industry was made (National Bureau of Economic Research, 1975) and it was suggested that approximately 5 % of the capacity of the industry would be endangered by the requirements of the law and 10 to 12 % would be potentially impacted. Those falling into the endangered category were relatively concentrated by region and sub-category, so there would be definite impacts on the general economy. The industry then filed a petition for a review of the Best Applicable Technology Environmentally Acceptable (BATEA) limitations in the US Court of Appeals. The industry and EPA jointly moved the Court for an indefinite stay of the BATEA limitations because the industry:

> *is engaged in continuing research and analysis, the purpose of which is to shed further light on the desirability and feasibility of the BATEA regulations and that the EPA is co-operating in the conduct of such research and is interested in the results it will produce* (Gallup, 1976).

A co-operative study was thus jointly initiated, developed and funded by the EPA and the textile industry. Later, a Settlement Agreement was entered into between the EPA and environmental groups in which the EPA was directed to reconsider the effluent limitations based on BATEA and develop new source performance standards based on the Best Available Demonstrated Technology (BADT) for direct effluent dischargers and pre-treatment standards for new and existing indirect (via a treatment facility) dischargers. These must consider an extended list of sixty-five classes of pollutants in twenty-one industrial categories (Gallup, 1976) and the list included benzidene (a constituent of diazo dyes), copper, mercury and their compounds. This case highlights the need for the public to be included at all stages in these situations, to prevent wasted money and time.

The most far-reaching environmental legislation ever introduced by a government, according to McPhee (1978), was the *Toxic Substances Control Act (1976)* passed by the US Congress. This was an expression of the concern of the US government over what it considered to be inadequately controlled use of massive quantities of chemicals. The law included environmental performance with that of end-use performance and economics in judging whether a new product should be marketed. The burden of proof was thus placed on the manufacturer to ensure that a chemical would not lead to significant adverse effects to health or the environment.

The EPA subsequently issued the *Textile Mills Point Source Category Effluent Limitations Guidelines, Pretreatment Standards and New Source Performance Standards* (EPA, 1982) and decided not to establish either best available technology (BAT) effluent limitations or New Source Performance Standards for colour. The decision was based on an evaluation of colour discharged by the textile industry in terms of the industry's national significance.

The EPA document (EPA, 1982) also states that colour in many instances, is simply an aesthetic pollutant, but in some cases, has been shown to interfere with the transmission of sunlight and the process of photosynthesis in the aquatic environment. In the textile industry, colour was deemed to be a mill-specific problem related to the combination of dyes and finishing chemicals used and for this reason, the EPA decided that colour should be controlled on a case-by-case basis by local authorities as dictated by water quality considerations.

3.3 THE EUROPEAN COMMUNITY (EC)

With the ending of superpower confrontation, the world order is changing rapidly and environmental issues are now high on the international agenda. In Europe, so long divided by ideological conflict, the prospect over coming decades is for economic convergence and collaboration. However, the magnitude of the task now facing leaders in both western and eastern Europe to facilitate that convergence is becoming more apparent. According to Russel (1991), it is particularly noticeable at the interface between economic and environmental issues.

The collapse of the imposed communist regimes in eastern Europe has not only ended systems of economic management in general, but industrial development in particular, under which *external costs*, especially environmental considerations, were ignored. It has also made possible official recognition of the serious environmental damage inflicted over the past four decades, but previously denied, suppressed or dismissed for ideological reasons (Russel, 1991).

Much of the new legislation on discharges to water is based on the EC Directive 86/280. In the last twenty years, according to MacDonald (1991), the European Community's initiatives have resulted in directives which have the potential to force plant closures if the clean-up costs are excessive and cannot be recovered. The advances in analytical chemical technology have led to increasingly sensitive techniques, which are able to characterise and trace pollutants to source. This has ensured that the *polluter pays* principle can be enforced.

With new legislation in the United Kingdom (UK) and the establishment of the National Rivers Authorities, pressure is being applied to all effluent dischargers to reduce water-borne pollution emission. This even applies to the water service companies themselves and the result has been a general tightening of consent limits and increased charges to cover the full treatment costs incurred by the water companies (Norman & Sneddon, 1991).

The Water Act, 1989 established the National Rivers Authority and the reorganisation (privatisation) of water services in England and Wales. The provisions of the Control of Pollution Act, 1974 were also revised and the principal changes of interest to the dye and textile industries are that they provide a statutory basis for establishing water quality objectives and increase the scope and effectiveness of regulations to prevent pollution. They also enhance the powers of the river pollution authorities to charge for applications for discharge consents and to recover monitoring costs. The Secretary of State is now also able to direct the authorities on the execution of their functions, with particular regard to EC and international obligations (D'Arcy, 1991).

Environmental quality standards have been set in terms of the new legislation and the local authority has to comply with them in the receiving watercourse. These standards are defined by the environmental quality objectives set for each watercourse, according to its assimilative capacity and water uses and each pollutant present in the effluent has to meet the relevant standard imposed. The National Rivers Authority's pollution control powers are contained in the provisions of the Control of Pollution Act, 1974 and relate to offences, the issuing and reviewing of discharge consents, keeping public registers and determining charges for consented dischargers. The maximum fine in the Environmental Protection Act, 1990 has been raised to £20 000 (D'Arcy, 1991).

UK regulations are based on the concept of the Best Available Techniques Not Entailing Excessive Cost (BATNEEC). The excessive cost entailed does not apply to the financial aspect, but that to the environment. BATNEEC applies to proscribed processes, such as those of the textile industry, which have been deemed to be hazardous.

In the UK, it is no longer permitted to dispose of chemicals or contaminated sludges anywhere except on controlled landfill sites. They must be removed from site by specialised waste disposers and the costs are high and rapidly escalating. Liquid effluent is the biggest problem for textile finishers in the UK and Europe, as the majority of companies discharge to sewer. Effluent is treated by the local sewage treatment plant before being discharged to a watercourse and the advantage in this option, is that capital investment and operational responsibility are kept to a minimum.

Part II of the Environmental Protection Act introduces a concept called *duty of care*. This requires that the producer of waste disposes of it in an acceptable and proper manner and means that more control of discharge has to be exercised. The net effect of these legislative and regulatory requirements is already having an influence on the textile industry. The two changes of most concern to dyehouses according to Cooper (1991), are the tighter control on heavy metals, particularly those known to be constituents of dyes and the emission of colour into watercourses.

For discharge to sewer, the cost of effluent treatment is determined by a trade effluent charging formula, based on the volume, chemical oxygen demand (COD) and amount of suspended material. There are certain restrictions on parameters such as temperature and pH and on certain chemicals. These have not caused major problems in the past, but the consent limits are now being more stringently applied.

European Textile finishers met in 1990 to consider the major problems facing the industry. These were identified as:

coloured effluent from reactive dyeing
coloured substances from the EC Black List (proscribed chemicals) and Grey List (those subject to further investigation)
biodegradability
metabolites
nutrients
pesticides
absorbable organohalides (AOX).

The Black (List 1) and Grey (List 2) lists consist of about 129 chemicals and the UK government studied these and formed a separate list of its own, which is commonly known as the Red List. Many of these chemicals appear in the effluent of textile finishers, for example, if caustic soda made by the mercury cell process is used, the process effluent will contain mercury, which appears on the Red List.

The standards, for colour in effluents discharged to treatment facilities and receiving waters are different in each of the EC countries. Within the UK, these standards also vary, but are usually based on the optical density of a water sample at different wavelengths. The discharge limits also vary depending on whether or not the effluent is discharged directly to a river or initially to a treatment facility.

3.4 THE REPUBLIC OF SOUTH AFRICA (RSA)

The authority of DWAF is vested in the principal act, the Water Act (Act 54 of 1956), and a number of amendments which have been promulgated since its inception. The most significant and comprehensive of these amendments was the Water Amendment Act (No. 96 of 1984). Sections 21 and 22 set out the conditions governing the quality of effluents and the methods of their disposal from the industrial usage of water. Section 23 deals with the prevention of pollution and these three regulations, promulgated in sections 11, 12 and 26 form the basis of the legislation used to control reductions in water quality and quantity. Murray (1987) claims, however, that it is effective only when administered enforcably.

The Act regulates coloured discharges for General Standard rivers under the heading:

> *Requirements for the Purification of Wastewater or Effluent*
>
> *The wastewater or effluent shall not contain any substance in a concentration capable of producing any colour, odour or taste* (Government Gazette, 1984).

Where an industry wishes to establish within a municipal area, it is required to conform with the industrial effluent by-laws of the local authority. These by-laws contain a charge formula for effluent discharge which varies with each area and contains a volume and *strength* (pollution load) factor. It is usually based on the ability of the sewage purification works to deal with the effluent in question and the formula varies with each local authority (Murray, 1987).

It is necessary for a local authority to enforce its effluent acceptance criteria, as it in turn, has to comply with the Water Act and the conditions of the permit issued by DWAF, which allows for the discharge of treated wastewater into a watercourse. The local authority may place its treatment facility and the well-being of the community at risk by not enforcing the by-laws. Many industries are forced to install pretreatment facilities on site, so that they may continue discharging their effluent to the local treatment works. If the local authority accepts an effluent in contravention of its by-laws, it may be guilty of an offence. The international trend towards privatisation of water treatment facilities, has led to increasing prosecution of them for offences. However, in South Africa, most of the municipalities act as environmental policeman and polluter, as owners of treatment facilities and thus the role of DWAF is essential in pollution prevention enforcement.

A trend in South African legislation is the increasing devolution of powers from central to local government, with the implication that industries are likely to become more involved with their local town or city councils and joint services boards and less with central government. It has been a feature of South African environmental legislation that practical and pragmatic approaches by the regulatory authorities have tended to prevail over bureaucratic dogmatism (Breyer-Menke & Moffatt, 1990). This is illustrated by the attempt at resolving the Umbilo River colour problem in Pinetown by involving most of the parties concerned.

The philosophy of future policies in terms of the environment, has been laid out in the President's Council's report (1991). Environmental policies were reviewed and recommendations made on an integrated national strategy for environmental management. The policy objectives included the need to maximise the net benefits of economic development, subject to maintaining the services and quality of environmental resources over time. It was also stated that pollution and exploitation of resources needs to be managed to maintain acceptable levels of environmental assets and services.

The need for a new ethic in South Africa as a prerequisite for the success of any new system of environmental management was realised by the President's Council and stated in the report (President's Council, 1991). Unless this new credo towards the environment, is adopted by all South Africans, no new policy will succeed in preserving our natural heritage. It was also argued that no individual or organisation could *own* the land, but that we are merely *trustees of the planet.*

Proper environmental and resource management is essential to ensure our survival and to promote a sound economy and the welfare of all (President's Council, 1991). This is indeed a new approach, in that a balance between development and the environment is advocated. In the past, the accent has been on furthering economic development at any cost, due mainly to the political and financial isolation of the country. The degradation of the environment and our natural resources has been a heavy price to pay, the burden of which we shall continue to bear for many generations. The homeland policy, which resulted in the forced removal of disenfranchised people to these areas and the ensuing overpopulation and misuse of marginal land, has left many areas badly eroded and unable to sustain the people.

The Report also realises that water needs to be better managed if it is to continue to be available in the quantities necessary to sustain and enhance the quality of life of all the citizens of this country. The Council recommends that further savings measures in industrial processes be researched in order that water quality and supplies are ensured. It also states that it is imperative that those industries and local authorities which affect the quality of water and return it to rivers and dams:

take responsibility for restoring water to acceptable standards, even if this involves additional capital investment (President's Council Report, 1991).

The Report also recommends that more effective control measures should be applied to those institutions causing water pollution, rather than addressing the symptoms of it. This has implications for the textile industry, not only in Pinetown, but throughout South Africa. The Report however, fails to set a timetable or the means for attaining these ideals and so seems set to become yet another paper exercise.

DWAF is gradually changing its approach to water pollution from the imposition of blanket effluent standards, to one of Receiving Water Quality Management Objectives and waste load allocations (Best, 1990). This approach focuses on the fundamental water quality management goal of maintaining fitness for use. This concept involves evaluation of water quality in terms of a particular user or category of users and thus ideal water quality is determined by its particular use and regulated by minimum effluent standards. Stricter site-specific standards may be imposed if the minima are not sufficient to maintain fitness for use of the receiving water body. They would be implemented in accordance with the Receiving Water Quality Objectives approach and based on the results of a waste load allocation investigation (Department of Water Affairs & Forestry, 1991).

It is recognised that not all users require the same quality of water and therefore supplies would go further and costs associated with purification would be reduced. The new approach also accepts that the aquatic environment has a certain capacity to assimilate pollutants without detriment to quality objectives. Hazardous and toxic pollutants should be minimised or ideally prevented from entering the aquatic environment.

The Department stresses that water should be managed judiciously and shared equitably among all users for the disposal of their wastes. The new approach accepts that water quality and water supply management should be fully integrated and this must allow the objectives of environmental conservation and economic growth to become complementary. One concept must become an incentive for the other (Best, 1990).

According to Toerien (1991), the approach no longer directly or indirectly, assumes an unlimited capacity for effluent discharge. Direct water re-use could increasingly be the result of dischargers having to upgrade the quality of their effluents. The changes in state spending priorities, as a result of political change and/or the development of deprived communities may result in a reduction of funds for water and environmental research. Such research may be vital to support the new management approach to water, but the need to develop the country economically, coupled with the poor state of the economy and a crippling drought, could cause this approach to be delayed or even abandoned (Toerien, 1991).

Best (1990) claims that growing world-wide public environmental concern is also evident in South Africa and was reflected in the outcry over issues such as seal culling and toxic waste importation. The opening up of South Africa through recent political events to international perspectives, will probably accelerate the process even further. The country will inevitably have to sign more international agreements on the protection of the environment.

3.5 THE PINETOWN SITUATION AND THE RELEVANCE OF THE COLOUR LIMIT

The limit set by the Department of Water Affairs for the Umbilo Wastewater Treatment Works' effluent into the Umbilo River is 80 Hazen Units. The textile industry and treatment works use the American Dye Manufacturers' Institute (ADMI) method to measure colour in wastewater and thus the limit set by the Department had to be converted into ADMI units for it to be relevant to the Committee.

It was determined that a solution which differs visually regardless of hue, from colourless to the same degree that the yellow platinum cobalt 100 standard differs visually from colourless, should also have a value of 100 in ADMI units. It was found that a multiplier of about 1 400 was necessary to yield a colour difference value numerically equal to the APHA value. The multiplier will differ in value from instrument to instrument, according to Allen et al (1972). This was corroborated using the Hazen and ADMI methods to establish the ADMI equivalent of 80 Hazen units set as a limit for colour in the Umbilo River. The results are shown in the graph in Figure 3.1.

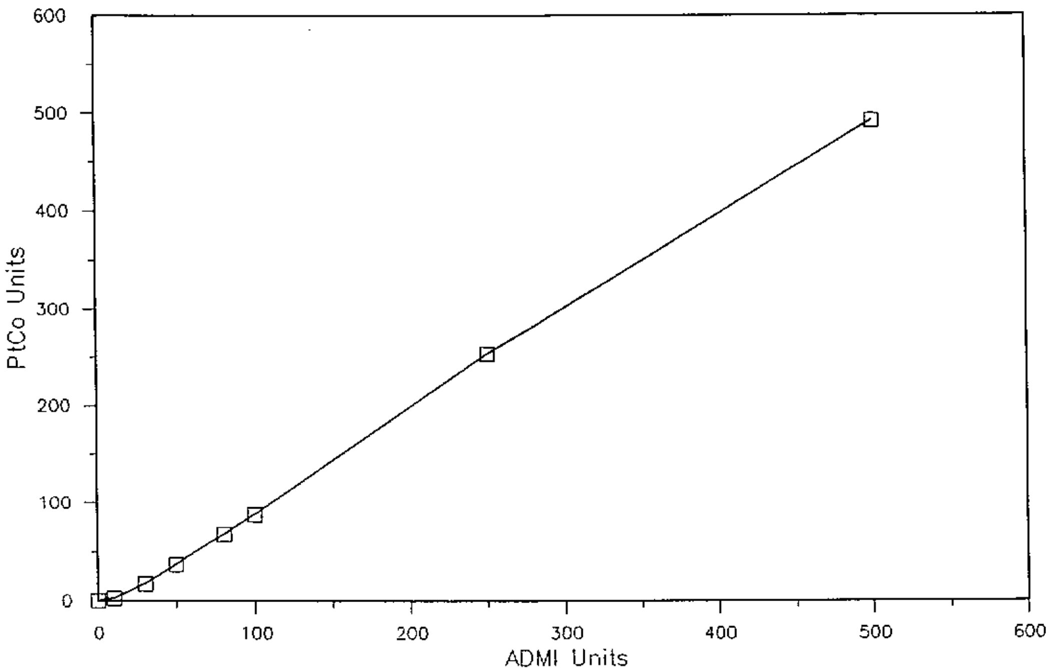

FIGURE 3.1: GRAPH OF PtCo vs ADMI UNITS

The methods employed to determine colour in Hazen units and platinum-cobalt units are identical, but no answer could be found as to why South Africa has preferred to adopt the name Hazen instead of platinum-cobalt units in water analysis.

The factories and Works' effluents are regularly sampled and analysed by the Borough of Pinetown. On sampling, the colour of the effluent is recorded on a scale of 0 to 5. If the sample appears to contain a lot of colour, it is given a rating of 5 and if it is relatively uncoloured, it is given a value of 0. The graph in Figure 3.2 shows the correlation between ADMI and this visual rating for samples taken at the factories prior to discharge of the effluent to sewer. It indicates that there is little correlation. Samples with a rating of 5, may have low, intermediate or high ADMI values.

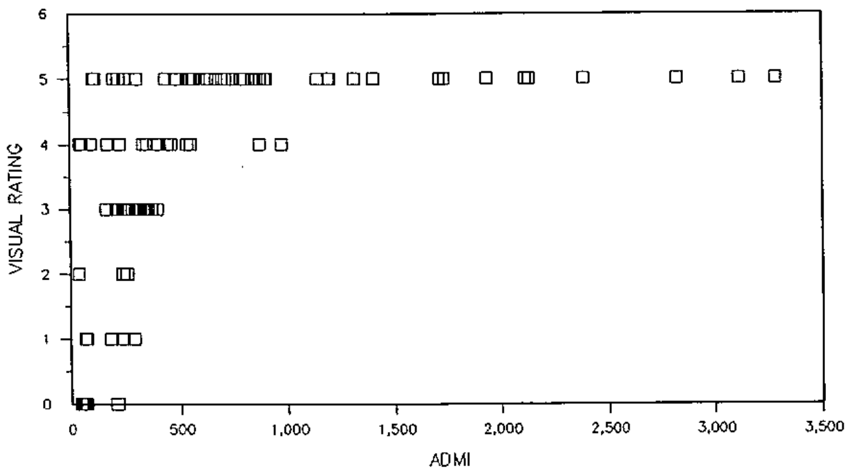

FIGURE 3.2: GRAPH OF COLOUR COMPARISONS ADMI UNITS vs VISUAL RATING

The graph in Figure 3.3 was drawn to determine whether or not certain colours were more likely to get a higher rating. The colours of the markers represent those noted by the sampler. Reds, browns and blacks were almost exclusively represented in the 5 visual rating range, with varying ADMI values. It has also been noted that complaints about colour in the Umbilo River are usually received when the Works' effluent is red or purple (Redlinghuys, 1991).

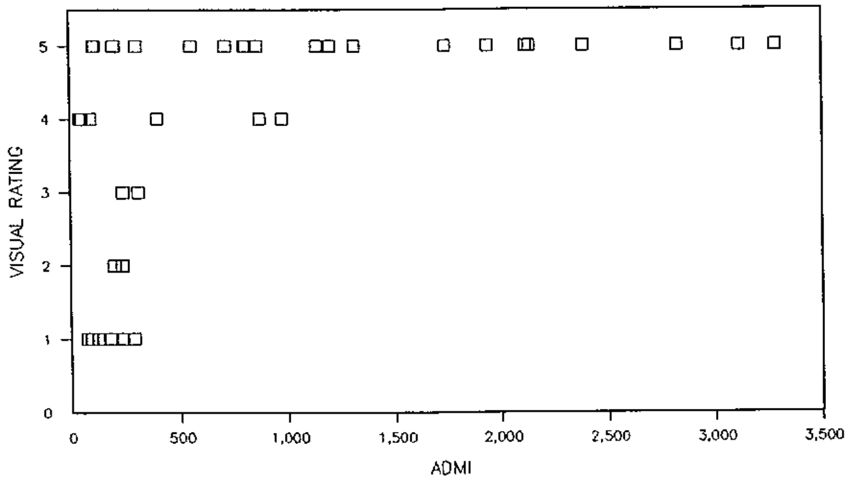

FIGURE 3.3: GRAPH OF ADMI vs VISUAL RATING
Sample Colours Illustrated

It can thus be seen, that if ADMI values are used to limit the amount of colour in the Umbilo River, complaints from the public may not cease. Those colours observed in the 5 visual rating range may still result in perceived colour, despite low ADMI values. An investigation should be made to determine if certain dyes appear more coloured than others, which would account for this discrepancy. These dyes could be subject to more stringent colour discharge limits.

Figure 3.4 shows the graph of the ADMI values recorded for the Umbilo River, above and below the Works' effluent outlet in 1991. The 80 Hazen Unit (80 ADMI) limit has been included, to show how it compares with the colour levels in the river. As can be seen, the levels above the Works often exceeded this limit, which excludes the Works' effluent as a causal factor. The colour is thus due to untreated effluent being discharged directly into the river.

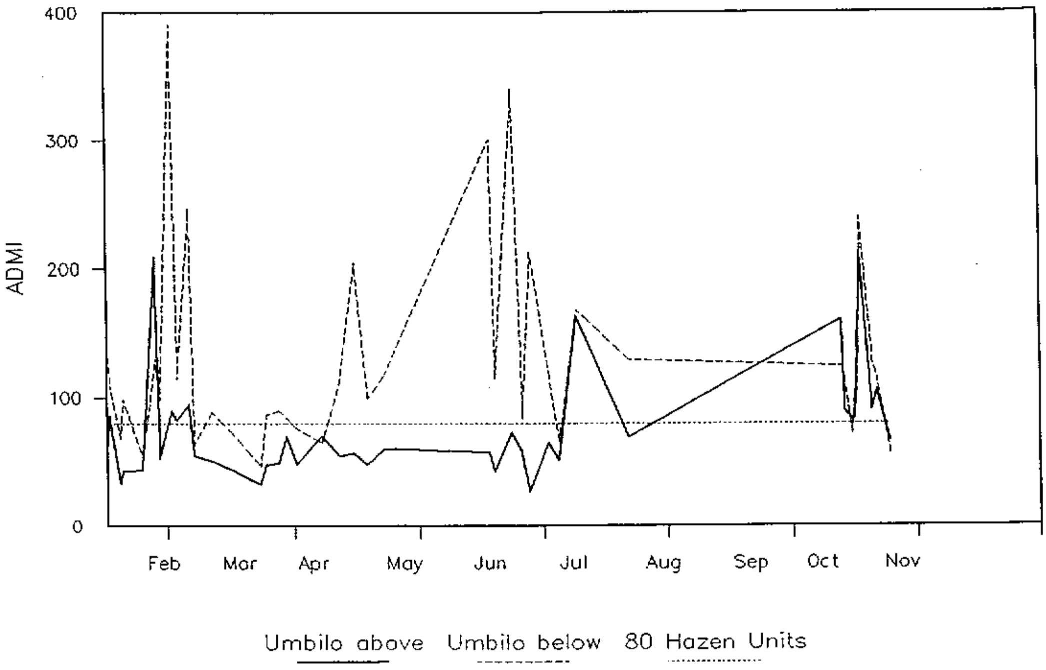

FIGURE 3.4: UMBILO RIVER ADMI
Above & Below Works, 1991

Colour in the Umbilo River above the Works has been recorded from sewer blockages at textile factories, due to obstruction by lint and rags and sewage surcharging directly into the river from blocked or cracked sewers. Some of these pollution events have continued for many days before corrective action by the authorities was taken, according to the Works' complaint register. Local Authorities must also be made accountable and liable for pollution and untreated sewage in the Umbilo River has more serious implications than treated, coloured effluent discharged from the Works. The colour levels below the Works usually exceed the 80 Hazen Unit limit and this is most noticeable in the drier season (June), when the river's flow is almost exclusively from the Work's effluent.

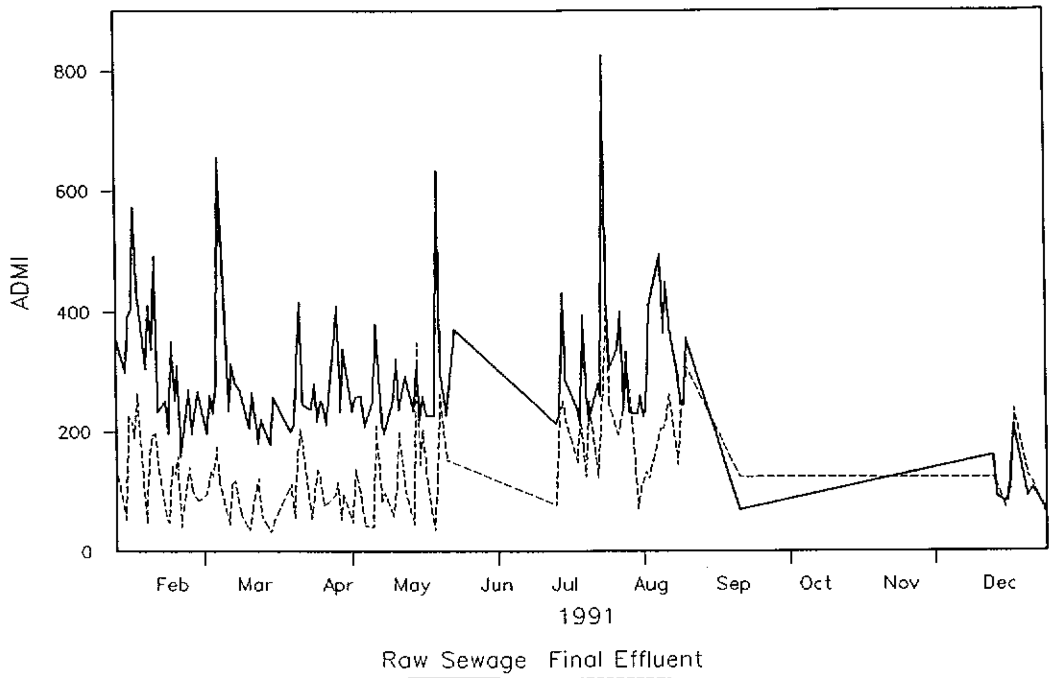

FIGURE 3.5: ADMI OF RAW SEWAGE & FINAL EFFLUENT
The Works, 1991

Figure 3.5 compares the ADMI of the raw incoming sewage and final effluent and shows that treatment does reduce colour, but not sufficiently to prevent colouration of the Umbilo River. To decrease the colour levels, alternative treatments are required to the biological methods used by the Works. The colour peaks in the raw sewage coincide with those in the final effluent and data was obtained from the records of the Works for 1991. No results were obtained for the months of June and September through to November.

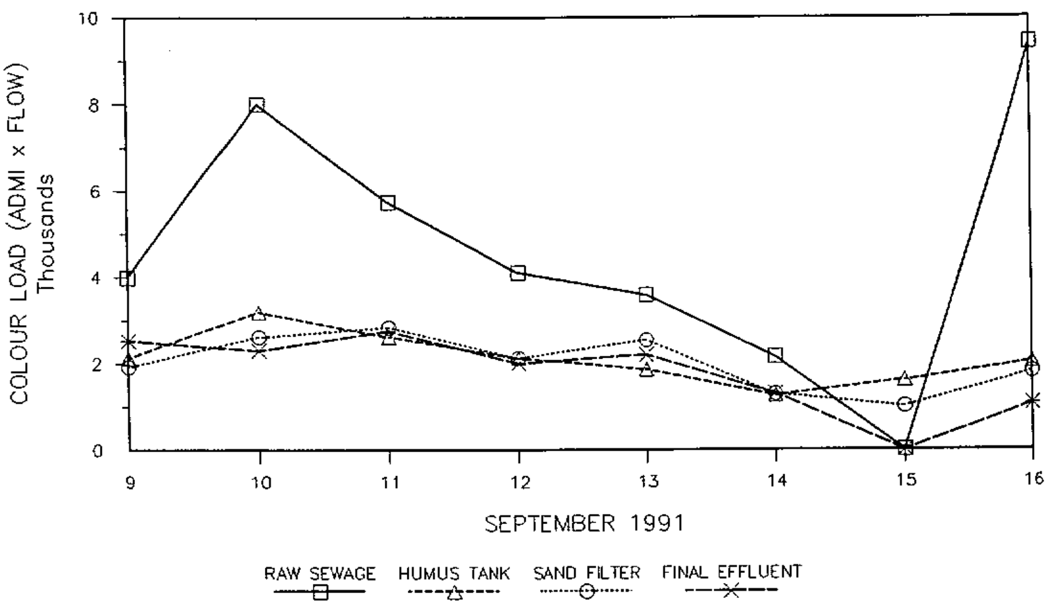

FIGURE 3.6: THE WORKS - ADMI LOAD
9/9/91 to 16/9/91

The graph of ADMI load of the Umbilo Works for the week starting 9/9/1991 is shown in Figure 3.6. The colour load was determined by multiplying the ADMI values by the Works' flow, which varies from approximately 7 Mℓ/day on a Sunday to over 13 Mℓ/day on a Monday. The different symbols represent the stages in the Works and include the incoming raw sewage, samples from the humus tank (after the trickling filters), sand filters and the final effluent after chlorination, which is then discharged into the river. The graph emphasises the fluctuations in flow and colour of the incoming effluent. The processes of the Works appear to have the same degree of effectiveness in the reduction of colour, in spite of these fluctuations.

The graph also illustrates the need for the textile industry to equalise their effluents prior to discharge to sewer. This is highlighted by the peaks of colour shown in the raw sewage ADMI. The Works appears able to maintain the ADMI of the final effluent below 200, however, this is not sufficient to prevent the colourisation of the river, especially in winter when there is insufficient dilution to maintain the ADMI below the 80 limit.

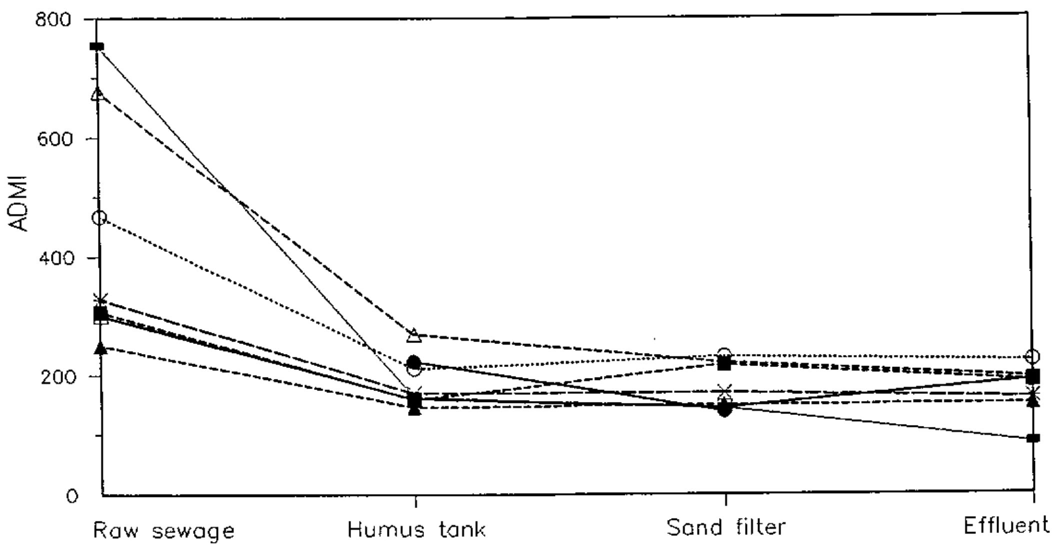

FIGURE 3.7: COLOUR REMOVAL PROCESSES
The Works, 1991

The graph in Figure 3.7 depicts the trend for colour removal in the processes of the Works. Each line represents a different daily sample (composited hourly samples) taken over a period of a week. The incoming effluent's ADMI's (composited hourly samples) vary from 250 on a Sunday to nearly 800 units on a Monday and the colour levels of the outgoing effluent remain within a narrow range, despite the incoming effluent's ADMI. It also indicates that most of the colour removal occurs in, or prior to the humus tanks. Chlorination occurs after the sand filters and appears to have no effect on the colour of the final effluent.

Two references in the literature however, refer to chlorination as a suitable means of decolourising textile effluents (Ghosh et al, 1978; Rhee et al, 1981). The chlorine concentration required for successful decolourisation however, prevents it from becoming a suitable alternative. Chlorine for final disinfection is being replaced in most treatment facilities in developed countries by ozone, due to the formation of toxic chlorine by-products which are increasingly being subjected to stricter legislation.

3.6 CONCLUDING COMMENTS

Although the prevention of the discharge of effluent containing visible colour into watercourses has been regulated by legislation for many years, this aspect of water quality has been neither regularly nor stringently enforced in South Africa. As environmental awareness has increased, so have complaints about colour discharged into rivers and oceans. This is a world-wide tendency, but the legislation preventing the discharge of colour into watercourses in Europe is far stricter than that in South Africa and the USA.

The USA is not intending to introduce legislation to prevent colour entering receiving waters, but is leaving it to the local authorities to deal with each case, if and when it becomes a problem. This approach seems sensible in light of the global economic recession and high rates of unemployment and the regional aggregation of the textile industry and should be pursued in South Africa.

The 80 Hazen limit set by DWAF for effluent discharged into the Umbilo River is too strict and should be relaxed. The river above the Works often exceeds this limit and thus the problem is not only related to textile colour. The impact of silt on the aquatic environment needs to be assessed, so that the impacts of colour may be realistically determined. The ADMI method for determining colour in industrial effluents is not ideal and further work is required to establish the effects of filtration on coloured effluents, relative to the class of dye involved.

The Works is able to decolourise textile effluent to a restricted ADMI range, no matter the ADMI of the influent. If the textile industry limited the peaks of colour and flow of their effluent, the influent and thus effluent, of the Works would be more homogenous. If the deeply hued (especially reactive red and black) dyebaths were discharged during peak flows into the works, dilution could achieve most of the decolourisation required. Once the peaks of colour and flow are removed and maximum dilution of colour is used, then the problem can be reassessed to determine the extent of colour remaining in the effluents discharged to the Umbilo River.

CHAPTER
FOUR

IMPACTS OF THE TEXTILE INDUSTRY

1.1 SOCIAL IMPACTS OF THE TEXTILE INDUSTRY

The textile and clothing industry is becoming increasingly globalised and as it does, more polarised. Production is concentrating in the east and south and consumption in the north and west (Anson, 1991). Intensified competition worldwide has led to major shifts in production to low-wage paying countries. The creation of international brand names has involved the manufacture of branded merchandise being made under license in different countries. Communications and technology have made this possible, ensuring information on products is instantly available and that shipment to far distant customers is no longer a hurdle. The key concept of globalisation, however, lies in everyone being able to sell in everyone else's market.

Globalisation of the textile industry occurred many years ago and has resulted in the emergence of multi-national companies and organisations that operate across state borders. There is often active co-operation from the governments concerned, who are anxious to create job opportunities in return for easing the way for the multi-national companies. The incentives include tax concessions, repatriation of profits and the subsidisation of plant and machinery in designated development zones. Textile manufacturing is usually among the first industries to be established in almost every developing nation and every developing economy aims to expand its textile sector (Buirski, (1992).

Textile manufacturers employ many non-skilled and therefore low paid workers. However, as a nation prospers, labour costs increase and the textile industry becomes vulnerable to imports from less developed nations. Textiles may eventually adversely affect a country's balance of payments, if protectionist measures (such as those employed in South Africa) are not introduced. Every citizen, however, is a consumer and the industry thus becomes a major factor in the national economy (Cooper, 1978).

The very rich countries have the highest fibre consumption per head, however, as countries become more affluent, they devote an ever-smaller share of their increase in wealth to clothing. Once basic needs have been met, clothing purchases become discretionary as wardrobes fill (Anson, 1991). This has resulted in producers in western countries facing slower market growth than firms serving developing markets such as those in South-East Asia. One way of keeping up the interest of consumers in western markets is to stimulate new demand by making products fashionable and raising quality of design. However, Anson (1991) notes that western producers no longer enjoy a monopoly of supply in such markets.

Many far-eastern countries benefited not only from the labour cost advantage, but in the second half of the 1980's, from the plummeting value of the American dollar and many prominent textile and clothing producing companies link their own currencies to that of the USA (Anson, 1991). Growing producer specialisation on a global scale has led to an increase in international trade over the last three decades. Developed countries responded with the Multi Fibre Arrangement (MFA) under the auspices of the General Agreement of Tariffs and Trade (GATT), in which quotas were set up to protect home markets. Despite this, all three major industrialised regions of the USA, the EC and Japan have seen their trade balances deteriorate.

Anson (1991) states that it is in everyone's interest that poor countries get richer, not only for humanitarian reasons, but also because these countries are then able to buy more western goods. So, while industrialised countries need to accept growing levels of imports from these countries, there also needs to be an arrangement for sharing the burden of import equitably.

The MFA, originally introduced to restrict imports of clothing and textile products from developing countries, lapsed in July, 1991. With textile wages in developing countries as little as 5 % of EC levels, most western countries are suffering, especially as their labour costs continue to rise. The growing social pressures on the need for conservation and increased environmental awareness, have created an uncomfortable feeling with many people concerning the built-in obsolescence of fashion. Clothing is thus being passed on or remodelled, rather than simply discarded (Anon, 1991). Taking into account all these negative factors, it is not surprising that the textile industry is under such stress world-wide.

Internationalisation presents opportunities as well as threats, as many successful firms in industrialised countries have discovered (Anson, 1991). Establishing wholly owned subsidiaries, joint venture operations or sub-contracting in low-cost countries is a way of exploiting geographical shifts rather than being beaten by them. Less-developed countries become pollution havens, whereby environmentally degrading processes controlled by legislation at home, are condoned by the host government, in order that foreign currency and jobs are generated.

Anson (1991) reports that in order for the EC's clothing industry to survive in the 1990's, methods will have to change to meet the requirement for greater variety, faster response and smaller batch size. Smaller batches and greater variety mean increased effluent volumes and differing effluent characteristics and therefore different effluent treatment requirements. Thus a general solution to the pollution from the textile industry is to remain flexible and to encompass as many treatment aspects as possible to be effective in the long-term.

South Africa is a developing country and can no longer offer cheap labour or resources to multinational companies. If pollution legislation were stringently applied, many industries would not be able to survive. However, if these measures had been introduced during the growth years, the implementation of environmental protection procedures may not have had the domino effect on the country, that the measures would have today. If companies spend money on environmental protection, jobs are usually cut to subsidise the capital outlay. If more people become unemployed, the country's social problems deteriorate further and less foreign investment will occur.

In South Africa, the textile industry is in a state of transition. Many facories have closed and others face imminent closure. The Department of Trade and Industry (DTI) appointed a committee to investigate tariff protection after the textile and clothing sectors reached a stalemate over a DTI programme, which envisaged initially higher tariff levels on fabric and clothing imports, while curtailing the existing import-for-export permits for garment producers. The textile sector, which claims it is losing business because of the garment and cloth imports under the scheme, supported the new measures. The Textile Federation reports that, of the R166 million worth of clothing imported to South Africa in the first half of the year, R58 million worth entered duty-free (Parker, 1991). The importation of second-hand clothing by church groups and charitable organisations for distribution to the needy has also troubled the textile industry. These imports are free of duty and a fee can now be levied by the distributor to recoup the distribution transport costs. Some companies, however, have used this loophole to import second-hand clothing and resell it for a profit which has resulted in a slump in new clothing sales.

The DTI's plan would have increased protection for textile manufacturers over the next three years. It would also replace a programme for the clothing and textile industries, devised by the Board of Trade in 1989, which was aimed at reducing protection for textile manufacturers. The battle is between the two industries, to decide which would keep or create more jobs. The textile manufacturers say thousands of jobs are at stake if it does not get more relief from imports. However, the clothing industry says it will create many more jobs if it can purchase cheaper textiles. The conflict has been one of the most high profile of many over protectionism raging in many sectors as South Africa tries to move away from decades of industrial protection (Anon, 1991).

The Board of Trade has in the meantime imposed stringent anti-dumping duties on certain cotton fabric imports. This tariff imposition is protectionist in itself and the clothing manufacturers hope that this does not introduce a new interventionist policy favouring the textile industry. The duty was apparently instituted after dumping of woven poly-cottons from China was proven, at prices that have disrupted the local market. However, the clothing industry claims otherwise and states that the duty was imposed unilaterally.

The DTI committee in April 1992, decided to institute a two-year transitional plan which could save 12 000 jobs presently under threat and make provision for 30 000 new posts (Anon, 1992). A tariff quota system aimed at limiting imports of clothing and textiles is to be introduced. Agreed quantities could be imported at current rates of duty and higher quantities allowed at a higher level of duty. The plan seeks to stabilise the textile and clothing industry by controlling disruptive imports, promoting the greater export of South African textiles and continuing to support the successful clothing export drive. The expansion of local cotton production as an input to the textile industry will also be stimulated by the plan, which will be followed by a longer-term plan aimed at stimulating growth in the industry. The strategy was the result of a new approach to industrial planning in this country, which included all affected parties, including the South African Clothing and Textile Workers' Union (SACTWU), in the negotiations (Anon, 1992).

The South African textile industry, which is valued at six billion rand, reported trading figures for the past years which show disasterous results, is in dire financial straits due to the downturn in the economy and the abolition of import duties. According to Cranston (1991a), no *significant* textile company is still working a full seven-day week and capacity was down from 87 % in 1989 to 75 % in 1990. Knitted fabric sales were down 22 %, woven fabrics 17 % and a bright future is not predicted.

The industry has experienced many retrenchments recently, with the Frame Group paying off 4 500 people over the last year alone. The workforce has been cut from 22 000 to 10 000 since June 1988 (Cranston, 1991b). This has been due to downsizing in the group and the downturn in profits largely due to the increase in yarn imports as part of the Structural Adjustment Programme. Textile industry wages quoted, at an average of R180 per week (Bennett, 1991), are amongst the lowest in the economy. This does not compare favourably with the R300 per week offered to workers in the motor industry for example, another sector experiencing economic difficulties.

There are approximately 7 400 people employed in the Pinetown textile industry. They are mainly represented by SACTWU which is affilliated to the Congress of South African Trades' Union (COSATU). A union official expressed concern at the prospect of environmental issues causing a confrontation between local residents, for example and the industry's employees. If pressure is placed on the industry to address environmental issues, such that the only way to meet the demands causes the company financial stress, workers could lose their jobs. This would place the union in a difficult position as it is sensitive to environmental concerns, yet exists to protect the jobs of its members (Bennett, 1991).

The Machine and Occupational Safety Act (Act No. 6 of 1983) protects employees in industry from the dangers of working with machinery, noise (mainly emitted from machinery) and dusts in the mill atmosphere. Hazards that face workers in textile factories have been reported by SACTWU as emanating mainly from cotton dust

(Bennett, 1991), which causes a form of emphysema known as brown lung disease. No reports have been received of problems caused by dyes or dyeing other than accidents due to the mishandling of chemicals or machinery.

To many South Africans, eliminating colour in the Umbilo River is futile and considered an exercise in aesthetics, while the money allocated could be better used to alleviate the hardships in our land. By placing the environment before employment and demanding that the textile industry decolourise their effluents, environmentally concerned people may lose popular support for other more universally relevant issues.

Some people would postpone beautification in South Africa until economic and social inequities are resolved and feel it selfish for some to enjoy life, while others are deprived. Others feel that social and economic injustices are intertwined with the wrongs committed against the environment and if environmental ills were healed, the other injustices would be righted simultaneously, as, through caring for the environment, people will learn to respect each other.

Khan (1991b) states that environmental issues in South Africa are rooted in politics and are seen in a strongly political light by those organisations which are concerning themselves with mass democratic rights. The broad common perception among representatives of these groups is that the accepted conservation ethos of South Africa's established environmental organisations is rooted in apartheid ideology and this ethos is seen to reflect the narrow class interests of a privileged sector of society.

Colonialisation, according to Khan (1991b), triggered a chain of historical events which destroyed the traditional relationship between early societies and the land. The effects and forms of this impact can be traced throughout the history of this country and can be identified as the direct origin of the political divides which characterise environmental attitudes in South Africa today. Apartheid is held responsible for the current difficulty that mass democratic organisations experience in identifying with established environmental groups and their programmes. Environmental organisations need to commit themselves to political principles with which the masses are able to identify and in this way, Kahn believes they will be able to win credibility.

The issue of colour in the Umbilo River must be approached with sensitivity to achieve a balance between people's need for employment and a clean environment. An assessment of the needs and wishes of all those affected by decolourisation of textile effluents is required, to ensure that the solution to the problem is endorsed by all. The environmental problems facing the textile industry have to be viewed against the cost of cleanup and abatement meaures. If protection of the environment by the textile industry is increased during the current recession, the only way to fund it would be by cutting back on the number of people employed. The industry has already retrenched thousands in 1991 and further labour cutbacks can only add to the misery and impoverishment of the people of this country. It is with this divergence of environmental interests in mind, that the problem of colour in the Umbilo River needs to be addressed.

4.2 ENVIRONMENTAL IMPACTS OF COLOURED EFFLUENTS

Environmental impacts include the effects on both the natural and the human environment. It is necessary to determine whether or not colour has an impact on the aquatic environment or on people who may use the river. It is also required to explore why people are complaining about colour in the river, to ensure that these are not based on misconceptions and that the Committee's solution to the problem addresses the issues of concern.

The Umgeni Water survey of environmental impacts of colour on the Umbilo River (Holmes, 1989) concluded that the effluent discharged by the Works had little impact on the quantity and diversity of aquatic fauna and flora. Silt must have played a role in reducing the state of the river, but colour has a similar physical effect (see Chapter 2) and some dyes are toxic. These impacts thus need to be studied to ascertain their relevance to the situation.

To determine the perceived impacts of colour on the aquatic environment, local residents, relevant societies and municipal organisations were contacted, as well as schools located in the residential areas adjacent to the Umbilo River. They were interviewed without the use of a formal questionnaire. Some of the people who complained to Department of Water Affairs, the local authorities and the Works were also interviewed, to ascertain their perceptions of the problem of colour in the Umbilo River and the implications of its removal.

4.2.1 Coloured Effluent Production

Turbidity is defined as a lack of clarity in water and should not be confused with true colour. It is very possible for water to be dark in colour, yet clear and not at all turbid. Turbidity is due to suspended matter, for example silt, micro-organisms, macro-molecules, matter derived from organic soil matter, mineral substances and many industrial pollutants. The measurement of turbidity is based on interference of light passing through the water. The more turbid the water, the higher the interference detected (Bratby, 1980).

So-called natural colour is derived from the presence of natural metallic ions (iron and manganese), humus and peat materials, plankton and weeds. When measuring colour in water therefore, a distinction is made between apparent and true colour. Apparent colour is due to suspended coloured matter and thus can be filtered or centrifuged out of the sample. True colour is that which is derived from organic sources (Bratby, 1980). In industrial wastewaters, the colour of a sample is considered to be the colour of the light transmitted by the solution after removing the suspended material, including the pseudocolloidal particles.

Coloured waters are objectionable for a number of reasons and the aesthetic consideration is especially important when supplying potable water. The presence of colouring matter is usually an indication of some form of pollution and steps are invariably taken to remove colour from water during treatment, especially in the case of potable water. However, as far as humic coloured matter is concerned, there is no evidence of it creating a health hazard, other than when it is chlorinated.

4.2.1.1 Textile Effluents

The disposal of textile wastewaters poses one of the industry's major problems, as they contain a number of contaminants, such as acid or caustic, dissolved solids, toxic compounds and colour. Of all these, colour is the most problematic, as it is visible to the human eye and thus susceptible to complaints from the public (Poots et al, 1978).

Industry and the state are becoming more aware of the need to clean up industrial effluents and reduce water pollution. The standards for the quality of a waste effluent are becoming stricter due to the semi-arid nature of this country, the increase in demand for water and the soaring costs of purification of increasingly more polluted water supplies. Certain industrial wastes cannot be treated by conventional methods of aerobic digestion and many dyes used in the textile industry fall into this category. The effective removal of dyes from effluents remains an important problem requiring resolution.

Commercial dyestuffs all derive their colour from the relatively complex chromophore system which they contain. A necessary criterion for their successful use is that they must be highly stable in light and washing processes and also stable against microbial attack. For these reasons it cannot be expected that dyestuffs in general, will be removed in short duration, aerobic biological processes. However, they are usually removed by physico-chemical means and some dyestuffs in longer-term biodegradative processes (Pagga & Brown, 1986).

Dyestuffs are complex organic compounds which may be refractory (non-biodegradable) to conventional treatment systems, given the aeration and retention times involved. Some may contain heavy metals (for example chromium, zinc, copper). Dyestuffs consist of other materials in addition to the dye component. Materials present in addition to the dye include dispersing agents, salt, sugar, sodium sulphate and other additives and reaction products.

Discharges of dyestuffs to the aquatic environment can occur from three principal areas. The first is during synthesis, but wastage to the drain is usually less than 2 %, according to Richardson (1988). Secondly, certain industrial users can also discharge considerable quantities, for example in the dyeing processes of textile manufacturing, where 50 % losses are not uncommon. Thirdly, dyestuffs may also be discharged from the household, usually during laundering, for example the bleaching of indigo from denim.

Coloured effluents have created problems elsewhere in South Africa and not only from the textile industry.

4.2.1.2 Paper and Pulp Effluents

Spent sulphite liquor is a by-product in the manufacture of wood pulp by the sulphite process. For every ton of sulphite pulp produced, one ton of spent sulphite liquor solids, is wasted or discarded, representing half of the original wood. The wood sugars and their degradation products account for most of the biological oxygen demand of pulp mill effluent when discharged to watercourses (Boggs, 1973).

Effluents from the pulp bleaching process are not usually recovered and it is these wastewaters that become the major source of pollution from many pulp mills. The effluent is high in colour and chlorinated lignin compounds and the highly emotive reaction it elicits in receiving waters can be compared with those of the textile industry. The effluent is a reddish colour and associated with odour pollution.

Newspaper articles have described the wastewaters from the paper and pulp industry with poetic licence, for example the article by Hotz (1986) was entitled *The Stained Sea.* It claimed that for thirty years, the Saiccor effluent had caused a public outcry and it was dubbed the *purple death*, *purple peril* and *coke*, due to its colour.

The Saiccor mill is situated on the banks of the Umkomaas River, south of Durban. It was built in the mid 1950's and the effluent was discharged to the surf zone off Umkomaas. This led to effluent entrapment and resulted in a darkly coloured sea which had the propensity to stabilise the foam generated by wave action in the surf. Frequent fish kills occurred when the effluent drifted up the Umkomaas River, pushed by strong incoming tides (Connell, 1990). The effluent has an enriching effect on the aquatic micro-organisms and they increase in numbers and aerobic metabolic activity, thereby reducing the concentration of dissolved oxygen. The lack of dissolved oxygen caused the fish to die. The effluent, when swept onshore by winds and currents caused foaming, sticky water, a sulphurous stench and strangely coloured seas. It has also been implicated as a causal factor in the reduced visibility over the Aliwal Shoal (now a marine nature reserve).

Saiccor's first effluent sea pipeline was 2,2 kms in length and was laid in 1968. It discharged the effluent beyond the surf zone, however, poor dispersion resulted in discolouration of inshore waters and there were many incidents of foam stabilisation. The pipeline corroded, was damaged by waves and had to be replaced. A replacement was laid in 1981, at a cost of R3,5 million. It fractured often and in July 1984 broke and the effluent polluted the Umkomaas River Estuary. This caused the death of fish and crustaceans due to the depletion of dissolved oxygen in the water (Hotz, 1986).

In 1986, the effluent was blamed for causing the decline in fish catches as it *poisoned the water* (Hotz, 1986). Saiccor admitted there were pollution problems associated with the mill, but claimed they were merely aesthetic. A survey was undertaken by the CSIR to determine the impact of the Saiccor effluent.

The beach meiofauna (smaller than 1 mm in size), the offshore biological communities of the sediments (intertidal zone, between the sand grains) and the organisms of the pelagic (free floating in the water) zone were assessed and no impact from the effluent was determined on the beach or at the end of the pipe. The effluent is warm and of a low density. It therefore rises very quickly and is easily dispersed by wind and currents (Connell, 1990). Peyton (1984) (in: Davis & Burns, 1990) claims however, that phenolic effluents, are toxic to mammals and fish.

The pollution problem was offset by the benefit the mill provided to the country as a whole. It employed 7 300 people, resulted in 18 000 *indirect* jobs and provided R325 million in foreign exchange per year (Hotz, 1986). In June 1985, a new magnesium-based plant came into operation, which reduced the solids load in the effluent. The complaints concerning the *purple death* did not diminish. In June 1986, DWAF gave Saiccor 5 years to reduce the ligno-sulphonate content by 80 % or to extend the pipeline, so that the effluent would no longer pose a problem to the shore. This new pipeline was the fourth in the history of the mill and was laid in 1987.

The concrete-jacketed stainless steel pipeline, 3 km in length and 900mm in diameter was laid at a cost of R27 million. The last half kilometer is fitted with spaced diffuser outlets designed to assist in dilution of the effluent. All unrecycled process liquor used in the pulping flows along a 4 km open effluent channel to a pumping station at the river mouth, from where it is pumped through the pipeline out to sea. The flow can amount to 3 800 m^3 per hour and may contain up to 2 % dissolved solids (Sappi Saiccor, 1990).

This costly solution to what the industry perceived to be an aesthetic problem, highlights the problems the Committee may face if public participation in the Pinetown case is not considered. If public opinion is not taken into consideration, the steps taken by the Committee to remove colour from the Umbilo River, may not be sufficient and more money may have to be spent in the long term, to the detriment of all those involved.

4.2.2 Dyestuffs as Hazard

The demand for brighter colours and improved qualities of light- and wash-fastness in fabrics has led to the development of various types of resistant dyes in the textile industry. Although pollution resulting from dye process effluents is highly visible, the toxicity of dye wastes was ignored until the 1970's. The higher-than-normal incidence of bladder cancer amongst workers involved in the manufacture of synthetic dyes was established to be due to intermediates as well as certain dyes (McPhee, 1978). These disazo dyes were synthesised from benzidine, now universally recognised as a carcinogen (Shore, 1991). The most hazardous have been phased out, but concern has been expressed as to whether or not other dyes themselves, as distinct from manufacturing intermediates, may constitute a hazard to workers and consumers.

Possible chronic risks of colourants and intermediates are carcinogenicity and allergic sensation. The reactive dyes have been targeted for examination, as they are specifically designed to react with amino and hydroxyl groups, which are present in proteins and enzymes in the human body. However, dyes have been declared safe once applied to the fibre, where their degree of fixation is high (McPhee, 1978). Exposure of wearers of clothing to dyes and pigments can only occur if the colourant has migrated onto the skin and for a toxic effect to develop, penetration of the skin must occur. Moll (1991) concluded that this danger potential of textile dyes is insignificant, as very low exposure, combined with an extremely minute skin penetration means that fast-dyed coloured textiles can be worn without harm.

Some dyestuffs, for example sulphur dyes, which are used extensively by the Pinetown textile industry, may be toxic in themselves. Winter & Kikuth (1989) established that sulphur dyes may interfere with aquatic metabolic cycles and under oxygen deficient conditions, organic matter is degraded by sulphur respiration. The sulphide formed is odorous, toxic and metabolises phosphates from the sediments, which results in accelerated algal growth. The organic matter produced is in turn degraded by sulphur respiration and anaerobiosis is the consequence. A lack of oxygen in aquatic environments prevents the system purifying itself and thus from being able to cope with pollution. The decrease in numbers and diversity of aquatic fauna and flora in the Umbilo River over the years, has been cited by some complainants as being due to the presence of coloured effluents, although the impact of silt must also be considered in this regard.

Biological treatment methods may degrade certain dyes, but the degradation products may be more toxic than the dyes themselves (Flege, 1968). According to the EPA's Office of Toxic Substances, azo dyes constitute a significant portion of submissions to the Premanufacture Notification process. The Office is concerned because some of the dyes, precursors, or their degradation products, such as aromatic amines (dye precursors), have been shown to be, or are suspected to be, carcinogenic. From experiments conducted by Shaul et al (1986), the fate of specific azo dye compounds in the activated sludge process was determined, but no overall predictions could be made. Azo dyes that can be split into specific amines (MAK-III) should not be used in textile dyeing, to ensure safe working conditions during processing, according to Moll (1991).

Azo dyes are by far the most important class of the current commercial dyes and over 50 % fall into this category. However, the lack of uniform data concerning the behaviour of dyes with respect to dye classes, highlights the need for each dye to be investigated for toxicity. These investigations must also be made in a case specific manner to ensure that the chemicals with which the particular dye is used, do not create additional toxic problems. For example, polyester dyestuffs, may require the use of toxic emulsifiers and leveling agents (Jones, 1973).

A research study undertaken by the American Dye Manufacturers' Institute in 1971 included an assessment of the effects of dyes on fish, aerobic and anaerobic systems and algae (Stahr et al, 1980). The dyes chosen for study were deemed representative of those used by the textile industry. The results showed that varying degrees of toxicity and/or process upset were noted with a significant number of the dyes investigated. Acute toxicity values for more than 4 000 dyes have now been analysed and it was found that 92,5 % of them had LD_{50} (dose required to kill half the test population) values greater than 2 000 mg/kg. The most toxic are in the disazo and cationic classes (Shore, 1991).

The actions of aminoanthraquinone dyestuffs on fish and green algae are apparently different and neither can be used as a prediction for the toxicity of the other. In respect of the toxic effect of dyestuffs on algae, the colourants which absorb light at the wavelength necessary for photosynthesis may inhibit algal growth through this essentially physical effect (Pagga & Brown, 1986).

The toxicity of triphenylmethane basic dyestuffs tested by the ADMI was noted, and C.I. Basic Violet 1 recorded the highest levels. The tests showed that the type and position of substituent groups in the anthraquinone parent molecule influences toxicity. It was also discovered that ethanol-amino groups increase the toxicity to both fish and algae and that cationic dissociation (basic dyestuffs) results in high toxicity (Brown & Anliker, 1988).

In the mid 1970's, the EPA led a large research effort designed to evaluate the toxicity of textile plant wastewaters and to determine the most effective treatment technology (Rawlings & Samfield, 1979). A priority list of pollutants was drawn up and techniques developed for bioassay testing. This was performed to determine the level of toxicity removal from secondary wastewaters achieved by the tertiary technologies selected in the study.

The tests assessed both environmental and health effects. The latter included testing for mutagenicity, carcinogenicity and toxicity potentials of the samples. Tests on the ecological effects focused on the potential toxicity of dye samples to vertebrates (fish), invertebrates (daphnids & shrimp) and plants (algae) in freshwater, marine and terrestrial ecosystems.

Of the 114 organic compounds in the priority pollutant list, a total of 44 different compounds were identified in textile wastewaters. From the bioassay results, it was generally noted that toxic effects detected in one test system were also detected in other systems. None of the effluent samples however, produced positive mutagenicity responses or resulted in acute toxicity effects in rats (Rawlings & Samfield, 1979). One may therefore conclude, that contact recreation (swimming, paddling) in the Umbilo river is safe.

Nine out of twenty-eight dyes tested for mutagenicity in an Ames (microbiological assay) test were found to be mutagenic (Friedman et al, 1980). These dyes were then used to determine whether residual mutagenic activity remains after dyeing. The results obtained suggest that in one case where nearly all of the dye is adsorbed by the fabric, not only do additional mutagens appear not to be formed during dyeing, but most, if not all of the mutagenic constituents originally present, either decomposed or were taken up by the fabric during dyeing. The authors suggest that further testing is appropriate to establish possible mutagenic hazards associated with dye production and use.

Basic (cationic), some acid and disperse dyes were shown to be toxic to fish and algae in bioassay studies and therefore are considered potentially hazardous. Acid dyes are resistant to biodegradation, but are usually produced in low concentrations in batch processes (<10 mg/ℓ). Vat, sulphur and disperse dyes, however, were determined to exert a negative effect on the self-purification ability of water bodies when discharged without adequate treatment (Kul'skii et al, 1986).

Gupta et al (1988), studied untreated carpet industry effluents in the Varanasi district of India, and found that they showed negative effects. The colour was determined to be aesthetically undesirable and it also increased the biological oxygen demand (BOD) of the receiving waters, thus disturbing the aquatic ecosystem. Metal complexes in some dyes degraded in the aquatic system and released toxic constituents above the permissible limit. Vat, sulphur and disperse dyes exerted a negative effect on the self-treatment in water bodies when inadequately treated effluent was discharged (Straley, 1984).

Some dye types are refractory organics which Cooper (1978) claims may degrade in an anaerobic system, such as a landfill, and leach possible carcinogenic metabolites. Conner (1987) reviewed land disposal of concentrated textile wastes, and considered them to be potentially hazardous. This was due to the metal content and because biodegradation of certain of the organic materials, especially dyestuffs, can produce carcinogenic and toxic chemicals as by-products.

Toxicity and adsorbtion of five azo and triphenylmethane dyes to freshwater microbiota was determined to assess the risks that they may pose to the aquatic environment (Michaels & Lewis, 1985). The basic dyes tested all showed relatively high toxicity to aquatic bacteria, especially the heterotrophs, at a concentration of 5 mg/ℓ. A loss of these micro-organisms could markedly decrease the mineralisation of organic compounds in an aquatic ecosystem and in addition, overall activity of the microbial community could also be reduced. The dyes were found to adsorb to bacterial cells at a much slower rate than that reported for pesticides, however adsorption could result in concentration of dyes from the water column into the microbial populations. These adsorbed dyes could then move up the food chain to affect other organisms in the polluted ecosystem, resulting in a decreasing ability for self-purification (Michaels & Lewis, 1985).

Solubility data are used to predict the potential for chemical concentration in sediments and biota. Many of the older disperse dyes that have published structures, have been identified as having a significant potential to accumulate in the aquatic environment (Baughman, 1988). Disperse azo dyes may undergo reduction in bottom sediments in the environment, resulting in the subsequent release of potentially hazardous aromatic amines into the water column (Weber, 1988).

The removal of colour by processes in a sewage treatment works has been summarized in the following flow diagram. It indicates where certain dyes can be removed during the treatment process and demonstrates how refractory the reactive dyes are.

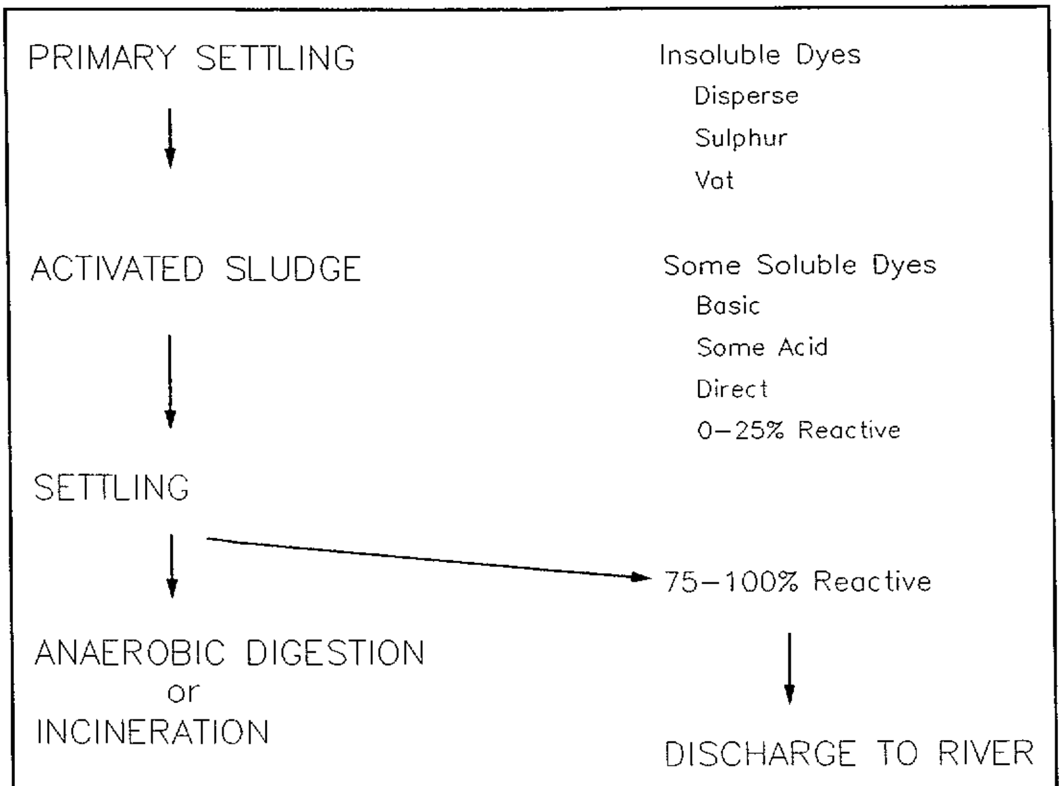

FIGURE 4.1: SEWAGE WORKS PROCESS FLOW AND REMOVAL OF DYES (After Pierce, 1991)

The most common means of treating wastewater is biological and some dyestuffs have been reported to be toxic to the micro-organisms used in wastewater treatment works. According to Nikiforov et al (1984), cationic dyes are biologically resistant and lead to the die-off of biomass in treatment plants. The authors thus advocate the use of sorbtion processes for treatment of these dyes.

The vast majority of commercial dyestuffs when discharged from industry or the home, will either be adsorbed on sewage works sludge or undergo at least primary biodegradation, particularly in the case of azo dyestuffs. According to Richardson (1988), three groups of dyestuffs are potential sources of hazard, the highly persistent ones, for example Rhodamine B, are most readily observed in rivers by the public, especially as they foam-concentrate on weirs and colour the concrete. Rise liquors from dyeing with reactive dyes are likely to colour humic and other materials in sewage and dyestuffs based on benzidene and its cogeners which have been shown to be carcinogenic.

Brown and Anliker (1988), however, claim that for most dyestuffs, aquatic toxicity data available demonstrates that provided any dyestuff discharge results in levels below those visible in a natural water, no significant risk to water organisms is likely. For those dyestuffs where this does not apply, it is important to consider levels of discharge both in factory effluents and following biological treatment.

The toxicity results reported in the literature, show that many dyes are hazardous and some of these pass through treatment facilities unchanged, while the by-products of treatment of other dyes may be toxic. The effect of some of these dyes on aqueous ecosystems may result in a reduction in the ability of the water course to assimilate pollution or may even directly degrade aspects of the ecosystem. Research into toxicity requires further investigation on a case specific basis, such as the effects of the dyes used by the Pinetown textile industry, which constitute the effluent discharged into the Umbilo River. An investigation into the effects of silt on the aquatic environment of the river also needs to be addressed, as this may be have a greater negative impact on the ecosystem than the coloured effluents.

One of the dye manufacturer's representatives divulged that they are notified of toxic dyes deleted from the catalogues on a monthly basis. The list consists of *approximately five dyes per month* and is received from their head office in Europe, presumably after the results of toxicity testing is known. Secrecy has never furthered any cause and this information should be published, to ensure that informed decisions are made by all involved in the textile and associated industries. The dye manufacturers, privvy to this information, should therefore be included in the Committee's proceedings.

4.3 PERCEPTIONS: COLOUR AND THE ENVIRONMENT

People move through a world of constant external and internal stimulation. Affected by the objects and events of our surroundings, we interpret them in terms of experience and our behaviour is modified accordingly. This constant interaction with the environment and the associated mental process of interpreting the impact and import of external events characterize the process known as perception (Murch, 1972).

All human beings share common perceptions and thus a common world, by virtue of possessing similar organs. No two people see the same reality and no two social groups make precisely the same evaluation of the environment. The scientific view is itself culture-bound and therefore is only one possible perspective among many. Of the traditional five senses (sight, hearing, taste, smell and touch), people are more consciously dependent on sight, to make their way in the world and are predominantly visual beings. Most people regard sight as the most valued facility and would rather lose a limb or become deaf or dumb, than sacrifice vision (Tuan, 1974). Human eyes are also remarkably discerning in colour gradations and the chromatic sensibility of normal vision boasts a degree of accuracy that is rarely surpassed in spectrophotometry. Visible aesthetic pollution thus elicits highly emotive reactions from most people.

Everyone has a different attitude to the environment in which they live and these views are not fixed, but often temporary and dynamic. According to the role one is in, whether property owner, factory manager or child playing, the environment will have different meanings at different places and times. The Umbilo River, when regarded as public property is often abused, however, when it is considered private domain, the resource is valued and attempts are made to protect and preserve it.

One of the more vocal complainants concerning colour in the Umbilo River lives on a property through which the river flows. He was responsible, through his senior position at work, for continual pollution of a tributary of the Umbilo River upstream of his home. During alterations to the factory, the sewage outlet was inadvertantly linked to the storm water drain.

The cause of pollution was traced to the factory and the complainant was continually (over a period of about three years) asked to rectify the problem. However, he refused to accept that contamination of the river was emanating from the factory and nothing was done until he was promoted. His successor was approached to address the problem and was able to trace the source of the pollution. The cause was established and immediately rectified (Redlinghuys, 1991).

At home, as a landowner, this complainant berates the polluted condition of the Umbilo River which runs through his property. He claims that *no price is too high to pay to clean our rivers*. However, in his capacity at work, he caused pollution during the same period he repeatedly complained to the authorities about how *they were killing the river*. At work his attitude to the river was that of a communal resource, which could be used indiscriminately.

The President's Council Report on a national environmental management strategy (1991) addresses this irony and claims that the specification of property rights can be an important determinant as to whether the resource will be used efficiently. The report states the *external costs* are those which spill over to *innocent* parties. As the polluter is not held accountable for these costs, they will not be motivated to take the costs into account when making resource decisions.

If a person pollutes a watercourse for example, this will result in cheaper effluent disposal charges than if the wastewater were pre-treated before discharge. The costs are then borne by the downstream users of the water, which are higher than would be the case if the polluter had to internalise these costs. If the polluter owned a stake in the watercourse and it became financially imperative that the water quality were maintained, the pollution costs would be borne by the person producing the effluent. The costs would be less when the pollution were treated at source, because the flow would be more concentrated and the constituents known.

More creative use of property rights could ensure that environmental and resource degradation be prevented in many cases. The industries in an area such as Pinetown, could became the trustees of the local environment upon which they impact (air, water and land). They could then pay subscriptions to its upkeep according to the scale of their particular processes' impacts. Monitoring of quality criteria and pollution events would then be transferred to those responsible for environmental degradation.

In their critique of the privatisation of land, the authors of *Commons Without Tragedy* (Andelson (Ed.), 1991) claim that the enclosurement of land in conjunction with the industrial revolution of the 1800's has resulted in the ecological disasters with which we are now faced. The result was that people were unable to subsist and rapid urbanisation occurred as they flocked to the cities in search of employment, a phenomenon reaching crisis proportions in South Africa, today. The answer to this dilemma, according to the authors, is to charge rent on land use and thereby ensure that it remains productive and sustainable. This would also ensure that the commons (rivers, oceans, skies and wildernesses, such as Antarctica) could be maintained for use by all without tragedy, such as occurs when each user tries to appropriate more than can be sustained.

A technical solution to the problem of colour in the Umbilo River is one that will require a change only in the techniques of the natural sciences. It will demand little or nothing in the way of change in human values or ideas of morality. A solution involving a change in the way people regard the environment, will be more far-reaching than one only involving technical changes. People need to be made more aware of the environment and the immediate and long-term implications of their impacts. DWAF, the Borough and the Committee need to look at ways of addressing this.

4.3.1 Perception Survey Assessments

All those interviewed were in agreement that colour in the Umbilo River was an aesthetic problem, however, some also claimed that it was having a detrimental effect on the aquatic environment. Some respondents said that there were fewer birds, crabs and fish, while others noticed that *life* in the water had diminished and this was defined as fewer species and individuals noticed in the river. The cause of this phenomenon was claimed to be either the toxicity of the dyes and/or the disruption of photosynthesis, as a result of the dyes preventing the transmission of light through the water. None of the respondents suggested that turbidity of the water after rain due to silt was responsible for the decrease in biodiversity.

Some of those interviewed described themselves as environmental activists and had joined action committees convened to improve the quality of the riverine environment. Other respondents claimed to have no environmental knowledge and complained about the colour as it infringed on the enjoyment of their properties. In one case, the complainant stated that his business was affected as the pollution, in his opinion, prevented people returning to the amenity he operated from the banks of the Umbilo River.

Most of the respondents said that they were prepared to pay more for their water, if it resulted in decolourisation of the river. Some said that they would not pay more, as it was not their responsibility. All agreed, however, that the polluter must pay and that this would result in higher prices of fabrics and garments, but they concurred that this was the correct place to recoup the cost of pollution control in the textile industry. Most of those interviewed were directed by prices when buying fabric or garments, but were adamant that if higher priced goods were the result of increased pollution control, then this information should be made available at the time of purchase. This would enable the consumer to make an informed choice between quality, price and/or environmentally acceptable production processes.

The respondents complained to many different organisations. One phoned the Works directly, another to the Westville Health Committee, Earthlife Africa and Umgeni Water. The latter complaint led to water samples being tested for faecal coliforms, whose levels were elevated, but not dangerously so (*sic*). Another complainant contacted DWAF, who inspected the river running through the property, but apparently did not pursue the problem. This complainant wrote a letter to DWAF in Pretoria and the Committee was convened as a result of the pressure brought to bear on DWAF in Natal (Gravelet-Blondin, 1991).

An estate agent offered the opinion that the houses which border on the river are usually valued at less than their neighbours' further away from the water, due to the threat of mosquitoes and floods. If the river has been made a feature and well integrated into the garden, only then, would the value of the property increase. If the river is polluted or if the banks are not well maintained, the value of the property through which it flows would decrease.

One of the complainants bought his property during the December factory shutdown period and another during the floods of 1987 when the colour and foam were not visible. On seeing the more *usual* river quality, they were bitterly disappointed and thus complained. The river is not used for industrial or agricultural abstraction, so water quality is only important for recreational and health reasons. None of the complainants appeared to be offended by the muddy nature of the river in the rainy season, and seem to accept this as a natural pheneomen. South African rivers have been degraded for so long, that few people remember clear water, and only those colours perceived as natural (brown, light blue or green), are considered acceptable. This has been corroborated by the Works' complaint register, which records purple and red as the colours most likely to cause complaints.

The complainants who contacted the Works were informed that the colour was caused by dyes used in the Pinetown textile industry, which were described as non-toxic and therefore the problem they caused was merely aesthetic. All of the complainants accepted this information and no longer perceived dyes to be hazardous.

One of those interviewed complained to the Queensburgh Town Council, which then referred the problem to the sub-regional Environmental Advisory Committee. This consists of representatives from the local authorities of Queensburgh, Pinetown, Westville, Kloof and Durban. A local environmentalist was approached to undertake a study for the Umbilo River Catchment Plan, but quoted thousands of rand to complete it and no-one was prepared to spend money, so it was shelved.

Another complainant contacted the Westville Municipality, who then approached the Works for comment. This person thereafter believed that the dyes only caused an aesthetic problem in the Umbilo River. Both the Westville Municipality and Queensburgh Town Council representatives approached were adamant that the costs for cleaning the water should be borne by the polluters involved.

A complainant contacted Earthlife Africa for help and advice, however, the volunteer who was dealing with the case resigned, so the matter was pursued no further. This person then contacted the local newspaper and asked them to run an article on the state of the Umbilo River, however, having a limited circulation, it did not achieve much in the way of publicity. A Pietermaritzburg water laboratory was asked to help a Queensburgh school, by testing water samples taken from the Umbilo River. The scientist was not asked to advise on the colour problem, merely to show the children how to sample and analyse water to determine the general state of the aquatic environment.

From the interviews, it was clear that many people had found the colour offensive and had raised objections at various fora, for example the Three Rivers Committee, the Environmental Forum and the Roosfontein Management Committee. No improvement in water quality ever resulted and the complainants felt frustrated. All those interviewed were pleasantly surprised to hear that a Colour Removal Committee had been convened and that it included the textile industry. They expressed an interest in ascertaining the results of the Committee's investigations.

Schools in the neighbourhood of the Umbilo River were approached to determine if they have been involved with projects in and around the river. They were contacted telephonically and by letter, but the results of their projects and surveys had little or no bearing on this investigation. However, the work done by scholars in environments such as the Umbilo River is important, in that levels of environmental awareness are raised.

European dyehouses are more environmentally conscious than their counterparts in South Africa, according to a representative of a dye manufacturer (Richner, 1991). This may be due to the pressures of the population on limited space and the increased standard of living which usually results in heightened environmental awareness. The European textile companies were willing to pay more for dyes that gave better results in respect of pollution prevention. This was not the case in this country, however, and most dyers choose dyestuffs according to tinctorial strength, application suitability and cost.

The South African dye marketing sector has enlarged recently with approximately six large and twenty smaller companies all competing for a share in the market. According to Richner (1991), the Taiwanese, Indian and Japanese companies offer cheaper, generic dyes. These dyes often lack reproducibility and thus require redyeings to match colours, which tends to increase the volume and concentration of coloured effluent.

Those interviewed who work in the textile industry admit that the industry needs to clean up its image by preventing further environmental deterioration. They also understand the need to implement pollution control measures before they become compulsory. However, the textile industry is in a depressed state and none of the factories in the Pinetown area commenced the 1992 year with full production, due to the decrease in orders.

4.4 CONCLUDING REMARKS

Colour in the Umbilo River is not merely an aesthetic problem. The dyes can have a physical effect on the ecosystem, by blocking sunlight and thus photosynthesis and the viability of the system is reduced. Some dyes may also have a direct toxic effect, but more work is needed in this area to determine the exact nature of these effects on the Umbilo River.

Pollution attracts more pollution and a river with polluted water is more likely to be used for dumping and the result is increasing neglect. The DMOSS initiative is not likely to suceed if pollution continues to degrade the riverine environment and the city requires a network of green corridors for health and recreation. Despite no formal extraction of water, the Umbilo River is used informally as a source of potable water and this is likely to increase with the informal settlements mushrooming in and around the Durban Functional Region. The river is a commons and the quality should be maintained for all users.

The textile industry is an important part of the socio-economic aspect of South Africa. It is struggling through the recession, but experiencing many retrenchments in order to survive. Public pressure to improve environmental performance will worsen this situation, however, the industry cannot continue polluting unabated. The compromise lies in cost effective solutions which involve the public.

Whatever the solution adopted by the Colour Removal Committee, the people affected by colour in the river need to be informed about the source of the colour and the extent of the wastewater's treatment. This should be in the form of a Committee reportback, to enable the spirit of co-operation established by the Committee members to be extended to those affected by colour in the Umbilo River. It must be relayed in a non-technical manner which can be understood by all, to prevent distrust and misunderstandings from developing.

The dye manufacturers and marketers also need to be included in the forum, in keeping with the philosophy of duty of care. Their experience and data bases of their international parent companies can be used to help overcome the problems associated with the use of their dyes and chemicals. They should also be included in the financial implications of the Committee and this would help to alleviate some of the economic hardships the pollution abatement measures introduce.

CHAPTER
FIVE

COLOUR IN THE UMBILO RIVER: - RESOLVING THE PROBLEM

5.1 INTRODUCTION

The textile industry transforms natural and synthetic fibres into fabrics, by processing fibres to form yarns, which are then woven, knitted or otherwise processed to create fabrics and these are then dyed, printed and/or finished. The process of finishing involves the treatment of a fabric that modifies its physical or chemical properties. Finishing includes features such as fire retardation, which reduces the flammability of textile fabrics and the introduction of soil release materials to aid in the removal of dirt and oil-borne stains. Most of these processes use chemicals that are resistant to biological treatment (Jones, 1973).

The rapidly increasing usage of synthetic dyes, new techniques and progressive technology in the finishing stages of textile production is directly responsible for the need to find new and efficient methods for the decolourisation of effluents. The traditional methods only achieve partial removal of organic matter and the most widely used methods of effluent purification are biochemical, however, the majority of dyes in current industrial use are only very slowly oxidised in biological plants. Subsequently their coloured effluents harm aquatic environments by upsetting the oxygen balance, retarding photosynthesis and suppressing natural purification (Shendrik et al, 1989).

Although mixing textile wastewaters with domestic wastes has led to successful treatment in the past, the increasing inertness of the effluents has rendered this approach less efficient. A research committee of the American Association of Textile Chemists and Colourists compiled a list of textile chemicals and determined the results of the five day biological oxygen demand (BOD_5) test for each. Out of 300 products, almost 40 % had less than 10 % BOD_5 by weight of chemical and were therefore relatively resistant to biodegradation (Committee RA58, 1966). Textile chemicals usually require longer retention times in biological processes, which is often not feasible due to the constraints on space.

Wastewater treatment works dealing with textile effluents need flexibility to deal with the changing constituents, which arise due to changes in fashions and therefore fibres, chemicals, dyes and processes used. This is often difficult to achieve in a municipal treatment works and raises the question of whether Pinetown textile industry wastewaters should be treated by the Works or on-site.

The auxiliary chemicals used in aqueous dyeing may also present a problem to biological processes. Carriers, for example, are used to accelerate the dyeing process and are usually discharged to sewer on completion of the operation. They are relatively inert, but may be adsorbed onto sludge and if this is not handled correctly prior to ultimate disposal, may pose further hazards in landfill leachate.

Waste disposal in South Africa is currently under review and the *duty of care* principle is likely to be adopted in guiding legislation. This will shift the responsibility and liability for waste to the producer. Landfill, as an ultimate form of disposal for wastes, will no longer be cheap and some form of pre-treatment will probably be required before disposal of textile wastes will be considered in future.

Due to variations in textile effluents from process to process and even from hour to hour, it is necessary to have some preliminary treatment on site. An equalisation tank will prevent peaks in discharge in terms of volume, colour and other characteristics, which is essential to prevent shock loading of the treatment facility. When on-site treatment methods are able to recover expensive chemicals from waste streams, these savings may fund new production processes that would have previously been considered too expensive. Thus, pollution prevention should not only be viewed as a financial liability, but an opportunity to reduce costs.

5.2 THE COMMITTEE'S OPTIONS

5.2.1 Treatment At Source

Treatment at source is most effective for any form of pollution, due to the concentrated and known constituents. It may involve separating flows, concentrating the effluent and then treating this part of the waste stream. It has been shown in Europe dyehouses that textile wastewaters can be treated effectively by installing a balancing tank on site that can hold effluent for 12 hrs to 3 days. This balances out the peak loadings with respect to dyes and pH. The tank contents may be neutralised with boiler flue gas, which would provide a simple and cost effective solution for alkaline effluents, for example (Richner, 1991).

The consultants, Explochem Water Treatment, established that there was a direct correlation between factory colour discharge and the Work's final effluent. It was estimated that 80 to 90 % of textile colour would have to be removed to achieve a significant reduction in colour in the Umbilo River (Explochem, July 1991).

Three colour removal technologies and their estimated operating costs were investigated. Adsorption and coagulation with cationic polyelectrolytes was established to be most suitable for Ninian & Lester and Fabrina's effluents. These two mills dye mostly cellulose-based and polyester fibres, using mainly reactive and disperse (anionic) dyes. Dye exhaustion on blended fabrics (polycotton) is lower (50-60 %) than for the pure cotton fibres (90 %). This results in more dye used to match colours on blended fabrics and consequently treatment costs will be more than those quoted for cotton.

Adsorption and coagulation with cationic polyelectrolytes resulted in 90 % colour removal, with 2 g/ℓ of flocculent and the cost is almost R14/m^3 when only the concentrated dyebath is treated. This is equivalent to approximately 14c/kg of heavily coloured fabric and would cost 231c/kg of dye used. Some yellow dyes were not effectively removed with flocculent and this phenomenon may be due to the small molecules responsible for this colour.

The cationic flocculent was not suitable for Universal Lace's effluent and this is due to the predominant use of acid dyes. Fenton's Reagent (ferrous sulphate) and hydrogen peroxide was effective in removing the acid and disperse dyes used by this mill. Decolourisation occurs by oxidation by the hydrogen peroxide radicals and the process is catalysed by the ferrous iron (Fenton's Reagent). For most samples tested, 90 % colour removal was achieved through a 10 g/ℓ addition of ferrous sulphate. This amounts to approximately R11/m^3, or 11c/kg of fabric for the darker dyebaths requiring treatment, especially those containing reactive dyes and red, brown or black hues.

Fenton's Reagent was used to decolourise Ninian & Lester's, Fabrina's and Twistex's effluent. There was good colour removal for most of the reactive dyes and all of the acid dyes tested and 90 % removal was achieved through addition of 10 g/ℓ ferrous sulphate. This would cost approximately R11/m^3 or 11c/kg of fabric, for those dyebaths requiring treatment. Twistex's effluent contains thickeners (and acid and metal complex dyes) and is thus highly viscous (and coloured). A ten-fold dilution of the samples was required prior to any decolourisation treatment being effective.

All flocculation/precipitation procedures will generate sludge, which may have to be disposed of in a landfill or slowly discharged to sewer, where it will increase the sludge load of the treatment facility. The ferrous sulphate precipitate improved microbial metabolism at the Works, however, in large amounts the effect may be detrimental. It has been shown that the floc formed by the use of the cationic polymers adsorbs the dyes irreversibly and so will not release the dyes on discharge to sewer.

5.2.2 Treatment At The Works

The Committee is considering treatment at the Works, as it would involve less capital outlay, than if each factory were to install its own equipment. However, the treatment costs would be higher than if it were performed on-site, as the effluent is less concentrated and mixed with other flows. A reduction in colour of the Works effluent may be obtained merely by slow release of the textile industry's effluent and by coinciding the discharge to sewer of highly coloured effluent, with the peak flow experienced at the Works, This would involve careful planning on the part of the textile industry, but would only require capital expenditure, if an equalisation tank of sufficient capacity to store effluent were required. If discharges of highly coloured effluent were timed to coincide with periods of peak flow into the Works, the dilution achieved could then be quantified and assessed for the necessity of decolourisation.

Trickling filters used at the Works, insufficiently decolourize textile wastewaters and an activated sludge process (ASP) is only slightly more effective. An ASP is being installed for half the flow of the Umbilo Works and thus may only marginally improve decolourisation of the effluent discharged to the Umbilo River. Some dyes have been implicated in impairing the functioning of the micro-organisms and thus the ASP will have to be carefully monitored for signs of metabolic loss or die-back of micro-organisms.

The sludge will initially require acclimatisation and thus micro-organisms isolated from textile mill draining sewers could be used to augment the micro-organisms in the activated sludge. Organisms that have already adapted to living in the presence of dyes or mutated, enabling them to degrade the dyestuffs, would result in the degradation of or adsorption onto the sludge of more dye and thus less colour would appear in the final effluent. Sludge obtained from the Southern Works in Durban, or the Hammarsdale treatment facility would be acclimatised to textile effluent and may be ideal for use at the Works.

5.2.3 Pipeline To Sea

Durban treats some of its coloured effluent in an activated sludge process and the water (often coloured) is then diverted to Mondi. This effluent requires decolourisation and activated carbon is used, which is a costly, but effective process, if the carbon is regularly regenerated. Effluent not used by Mondi, is discharged by the Southern Works to sea, by means of an extended ocean outfall or pipeline, which is a common means of disposing of wastewater for coastal cities. The coloured effluent has not been found to adversely affect the marine fauna and flora (Connell, 1990), however, recent international studies have been focusing on the detrimental effects of sewage sludge deposition on the ocean floor.

It was been suggested that if no suitable solution to the problem of colour in the Umbilo River is found, the prospect of a pipeline to discharge the effluent to the sea should also be considered. This is an expensive alternative and one which simply moves the effluent to pollute another environment and thus is not an holistic solution, in terms of environmental management.

5.3 OTHER OPTIONS

It is now being generally accepted in industry, that the subject of environmental issues is not a *fad* and will not fade away. The challenge is to deal with the issues, implications and requirements of stricter operating requirements in a positive way, yet still maintain a healthy economy. A balance between the threats and the opportunities needs to be created and the former arise from the increasing amount of legislation and regulations that is being enacted and the consequent cost implications of non-compliance. The opportunities arise from considerations of better control; improved efficiency; waste minimisation, recovery, reuse, recycling and perhaps the most important consideration, consumer demand (Cooper, 1991).

Green issues are usually fuelled by affluence, puritanism and a distrust of scientists, according to Cooper (1991). Explanations by scientists often confuse the public by being too technical and complex and it may be perceived that they are defensive and trying to hide the truth. The green movement is often not susceptible to reasoned argument, but companies cheating on green issues stand to lose more in the long term if they are caught, than they gained in the short-term by cutting corners.

There is evidence in UK market research that 36 % of the adult population is prepared to pay more for products that specifically and significantly help to improve the environment (Cooper, 1991). As producers of goods, the textile industry must consider public opinion as consumers will increasingly select products that are perceived to be environmentally sound. The *duty of care* and *cradle to grave* principals apply in most developed countries and require that producers ensure that their products are produced and ultimately disposed in an environmentally acceptable manner. The consumer is now demanding to know that goods are being produced in an environmentally acceptable way and by being proactive in this regard, the Pinetown textile industry can publicise its efforts and improve its environmental image.

5.3.1 Environmentally Acceptable Clothing

An option for the textile and finishing industries to solve the environmental problems they face, may lie in the production of a *green* range of products. This would involve a simultaneous education and marketing programme, by providing an explanation of the effluent problems, their solutions and the costs involved on a label attached to the garment or material. It could coincide with an aggressive advertising campaign of a generic nature - one that involves all the Pinetown textile industries and promotes the pollution prevention initiative that is taking place.

The garments or fabric would be unbleached by chlorine, printed or dyed with only those dyes known to be degraded by a conventional wastewater treatment facility or if dyed with *problem* dyes, the effluent would be treated in such a way as to ensure compliance with all discharge criteria. This would mean that the product would be more expensive, but if the advertising campaign were aimed at the most receptive market, then the cost would not deter the targeted consumers. The environmentally concerned person needs to feel that they are *doing something to help* and thus are usually willing to pay extra for a product produced with environmentally sound processes.

5.3.2 Alternative Dyes

Facing prohibitive research and development costs, dye manufacturers are curtailing pollution by introducing stronger, more highly concentrated versions of existing dyes. This reduces the amount of dye used and therefore less colour is discharged to sewer. Shelley et al., (1993) established that reduced packaging and lower transportation costs have also led to savings. Historically, inconsistencies in the dye strength of crude dyestuffs have forced dye manufacturers to rely on dilution to create standardised, consistent dyes. Due to an improved understanding of chemistry and high technology equipment, raw dyestuff of higher quality is being produced. As a result, the concentrated dyes, carry 2-4 times the concentration of active ingredients, compared with, in the past, typical dyes carrying as little as 4 % or as much as 60-80 % active ingredients.

Dye manufacturers are creating new dyes and modifying existing ones, to improve colour fixation properties. This will reduce the amount of dye discharged in textile wastewater and reduce the use of auxilliary chemicals. Shelley et al. (1993) noted that traditional reactive dyes contain only a single functional group, but now dye manufacturers are combining several reactive groups in a single molecule. In bifunctional reactive dyes, each reactive group compensates for the other during changing process conditions, improving colour fixation and producing more predictable and reproducible dyeing. This will in turn reduce the colour and the volumes of effluent produced.

The bifunctional reactive dyes have reduced dye in effluent from 40-50 % to only 10-20 % wastage, which is a tremendous advantage in resolving the problem of colour in rivers. These dyes are more costly, but the improvement in colour fixation from 50-70 % to 75-95 % may offset the higher price, as dye usage, auxilliary salt consumption and the volume of dyes in effluent is reduced. For some applications, higher fixation rates can also cut dyeing time in half, according to Shelley et al. (1993).

The authors also established that research into modifying the cotton fibre has also improved dye fixation. Polyfunctional reagents have been used with reactive dyes that have been combined with suitable amines to create nucleophillic dyes. This process has increased colour fixation to 96 %. Sulphur dyes have been improved to include a mix of non-sulphide reducing agents, which cut sulphide consumption by 48 %, which in turn, translates to a 30 % reduction in the amount of rinsewater needed to remove residual sulphides from the dyed fibres. Although these dyes are also more expensive, dye usage can be cut by 25 %, according to Shelley et al. (1993).

To reduce the volume of dyes in effluent during disperse dyeing, which are typically carried in aqueous solution, a dye manufacturer is working with a team from the textile industry to develop a range of dyes that can be carried in supercritical carbon dioxide, instead of water. Fixation rates of 100 % can be achieved, with no wastewater being produced, but is currently limited to dyeing polyester, aramids and polypropylene (Shelley et al., 1993).

There is a new biotechnological approach to the production of textile dyes that may alleviate the effluent problems associated with conventional chemical synthesis. The new dyes are produced from genetically engineered bacteria and are claimed to be able to replace existing vat, mordant and disperse dyes. They also claim to introduce new opportunities relating both to the shades obtainable and such properties as stability and fastness (Anon, 1989). However, they have not yet been produced commercially, so the claims require validation.

Underscoring the environmental pressures that are driving the dye manufacturing industry, Shelley et al. (1993) noted that one dye maker spent more than half its 1992 research programme on environmentally driven projects. The companies are striving to find ways of reducing the amount of salt, hydrolysed dyestuff and heavy metals in dyehouse wastewater and thus this quest is not only limited to the dye users, but shared by the dye producers alike.

Further investigation is necessary to determine which dyes used in Pinetown pass through the treatment facility untreated or pose a hazard to public health, the Works or the aquatic environment. Dye manufacturers must become involved and supply the information required, as the perceived cloak of secrecy adopted can only harm the industry's image further. Alternatives to the problem dyes should be offered and if none exist, these specific dyestuffs can be targeted for specific treatment at the dyebath, before discharge to sewer. Analysis of the chemistry of the dyes which are mixed together in the factory's holding tank should be made, to try to make optimum use of chemical reactions to minimise problems with effluents. For example, the acid and basic dyes could be discharged to neutralise each other, while use of those which precipitate others would reduce treatment costs.

5.3.3 Colour Standards & Public Education

If colour in aquatic environments were merely an aesthetic problem, the public should be educated accordingly and public participation in the Committee's work, especially involving the media, would achieve this. However, the problem is not only aesthetic, as it also seems to affect the receiving waters, so the maximum amount of colour allowed into the watercourses should be determined, to ensure that photosynthesis and self-purification in the aquatic environment is not impaired. This upper limit should then be publicised through the Committee and the public made aware of the implications of colour in watercourses. We seem to have become used to the amount of silt that our rivers carry and are no longer perturbed at the sight of muddied waters, however this must also negatively impact on the watercourses and thus needs to be highlighted and addressed where possible. This is the responsibility of DWAF and should be addressed by education of people living beside rivers, the public that use rivers, whether as an amenity or a resource and those owning land in which the headwaters arise.

The difference between high ADMI values and perceived colour was shown in Figure 3.3. By placing only an ADMI limit on effluent discharges, the colour complaints may continue. An attempt should thus be made to establish a correlation between the high visual rating some colours achieve, despite recording relatively low ADMI values and the classes of dyes involved. If a certain class is always perceived as highly coloured, but not in terms of ADMI values, then it should be more stringently controlled in terms of discharge and pretreatment required.

The regular complainants concerning colour in the Umbilo River could be invited to an *open day* at the Works, which could involve a tour of the facility and explanations of the colour problem. These people could then be invited to participate in the study of colour perception versus ADMI values. This would make the technological process of resolving the colour problem more likely to be understood and accepted by the public involved and thus the number of complaints should decrease.

5.4 CONCLUDING REMARKS

Pollution problems must be addressed by establishing the sources and types of pollution. The simplest solution is provided if the pollutant can be eliminated or replaced by a non-polluting alternative. If not, treatments as close to source as possible, should be investigated and *end of pipe* solutions only used as a last resort. Having determined the origin and nature of the pollutant, it is easiest to treat in its most concentrated form and only when the main elements of pollution have been treated, should the effluents be merged for discharge.

Before opting for expensive treatment of effluent, it would be more effective if the use of dyes were investigated. It is imperative that the international experience and expertise available from the dye manufacturers be used and thus they need to be involved in the Committee. If the dye problems can be reduced by making use of alternatives that have higher fixation rates, it would be more effective than treating an effluent stream. Dilution of highly coloured effluent by discharging during peak flow periods should be implemented as soon as possible.

A similar study to that performed by Shaul et al (1991), the results of which are shown in Table 2.6, should be performed specifically for the Pinetown situation to determine which of the dyes used by the textile industry has the potential to colour the Umbilo River. Those dyes that pass through the Works should be identified and surveyed for hazardous effects in aquatic environments or on human health and replaced if possible, on the advice of the dye manufacturers involved.

Usually only the darker hued dyebaths (reds, blacks, browns) result in the production of coloured effluent being discharged to the Umbilo River by the Works, therefore, these dyes should be considered for treatment at the dyebath. The literature should be closely monitored for toxicity testing of dyes, especially the azo dyes, as they may have the propensity to produce toxic by-products.

The Committee should involve greater public participation to ensure it is on the right track and to generate a positive image for the Pinetown textile industry. The public is usually willing to compromise if it is perceived that a solution is being sought, if people are informed of the facts and limitations involved, positive attitudes to the industry and its problems will be generated.

CHAPTER
SIX

CONCLUSIONS AND RECOMMENDATIONS

Colour in the Umbilo River is derived from the discharge of effluent from the Borough of Pinetown's Water Treatment Works. The colour originates from dyes used by the Pinetown textile industry, some of which are neither degraded nor adsorbed by the treatment processes utilised. People living near the river or using it as an amenity complain about the colour, as they associate it with raw, untreated pollution and feel that it is degrading the water quality.

The problems associated with colour in aquatic environments are universal where textile mills are aggregated and the Pinetown situation is such a case. The effects of colour are not only aesthetic and thus need to be addressed. Colour interferes with the transmission of sunlight into water and thus decreases the photosynthetic capability of the aquatic environment, which in turn affects the amount of energy available to the system. This has a cascading effect on the ecosystem and results in a reduction in its self-purification ability, as well as a decrease in the numbers and biodiversity of flora and fauna. This latter phenomenon cannot be exclusively attributed to coloured effluents, as the silt load of the river and colourless, toxic constituents of discharged effluents must also play an important role in reducing the quality of the aquatic environment.

The continuous damage to the environment caused by silt is seldom acknowledged by the public. People appear to have become used to muddy rivers and perceive the brown colour to be natural, yet it is a form of pollution which has been identified by DWAF as a factor requiring urgent attention in the attempt to address the lowering quality of water available in South Africa (Department of Water Affairs and Forestry, 1991). Natal rivers are usually fast flowing due to the steep topography and have eroded catchments and river banks as a result of farming malpractices and high density settlements. This results in a large silt load, especially after rain episodes. The turbidity of the Umbilo River could be an important factor in the degradation of the the aquatic environment, as it will decrease the amount of incoming light and thus the photosynthetic capability of the river. This in turn, will result in decreased numbers of individuals and species of aquatic fauna and flora.

Some dyes, especially the reactive class, have been developed to resist biodegradation and thus pass through the treatment facility unaffected and colour the receiving waters. Other dyes, including azo dyes, have been implicated in toxicity to people and the micro-organisms of biological treatment processes and/or aquatic ecosystems. The Works' effluent requires classification as to dye content, to determine which dyes or classes are responsible for the persistent colour in the river. These dyes could then investigated for substitution with those that can be decolourised at the Works, or specifically treated at the dyebath where they will be most concentrated. This will also reduce capital outlay and thus the cost of treatment can be assigned to a specific batch and not to textiles in general. Those dyes identified in the literature as being toxic, must be replaced with suitable alternatives, on the advice of the dye manufacturers involved.

The 80 Hazen colour limit set for effluent discharged from the Works is too stringent and requires relaxation. Comparisons between analytically-derived colour intensity and that which has been determined visually has revealed that an effluent which may seem highly coloured to the human eye, may reflect low or high ADMI colour values. This discrepancy is not restricted to certain colours, for example the darker hues and thus requires careful evaluation to ascertain whether certain classes of dyes are more likely to display this characteristic. If only an ADMI limit on colour is set for discharging effluent from the Works into the Umbilo River, the complaints may persist, as the water may remain visually (not analytically) intense for these dyes. More than one limit for discharge from the Works, which will vary according to the dyes the effluent contains, may thus have to be set.

Decolourising textile effluents is the aim of increasingly more stringent legislation in Europe and the USA and many constituents of textile wastewaters appear on the lists of substances prohibited for discharge to watercourses. Many textile mills facing such legislation are unable to meet the new requirements, so have already or will have to close in the future. As the textile industry is usually aggregated in regions, this will have a ripple effect on the economy and unemployment in that region and thus the nation as a whole. Legislation is more frequently evolving through consultation with all the parties involved to reach feasible solutions and this is the manner in which the Umbilo River problem is being approached and it is to be commended.

The Committee was formed consisting of representatives from the textile industry, the Works, the Department and the University of Natal and it employed consultants to test different methods of decolourisation identified in a literature search. The most cost effective means were tested for feasibility on-site or at the Works. Although treating effluent streams on-site is more effective, it may require a major capital outlay, which treatment at the Works does not. Several interested and affected parties were excluded from the procedings and they include the users of the Umbilo River (complainants, local residents and amenity owners), the trades' union representing textile workers and the dye manufacturers and marketers. Without representation from these groups, the options adopted to solve the problem of colour in the Umbilo River, may not address all their concerns and thus not resolve the issue.

A public education programme, outlining the steps taken to reduce colour in the Umbilo River and the amount that can be discharged without affecting the quality of the aquatic environment, should be implemented. This should form part of the participation by the public in the Committee's proceedings, as informed people may be more sympathetic of the conflicts involved in decolourising the Works' effluent. Representation from the trades' union is imperative to ensure that the opinions of the textile workers are considered, as their jobs may be threatened if costly decolourisation methods become mandatory.

An assessment was made of why complainants found colour in the Umbilo River offensive and most felt that it was toxic and responsible for degrading the environment. On learning the problems associated with decolourisation, including the expense and possible loss of jobs in the textile industry, many people expressed their willingness to pay extra for clothing if they knew that it were produced in an environmentally acceptable manner. A *green* range of clothing launched by the Pinetown textile industry with an advertising drive, would highlight the pollution problems the textile industry faces and gain consumer credibility for their efforts in resolving them.

Most people interviewed would be unhappy to pay more for potable water to ensure that the Works decolourised the effluent, as they felt the polluter must pay. One of the complainants was very aggressive in his determination to have the Umbilo River decolourised, but at work was negligent and responsible for chronic pollution of the river by raw sewage. This dichotomy of attitudes to the environment was commonly evident, with one attitude prevalent at home (a need to enjoy a clean environment) and another at the place of work (exploitation of a commons).

The South African textile industry is important in terms of job opportunities and its contribution to the economy. If increased environmental standards are applied, the cost will probably be offset by retrenchments and an increase in mechanisation. The country cannot afford this in these times, where violence, poverty and unemployment form the pillars of increasing hopelessness.

It can be seen that the solution to the problem of colour in the Umbilo River is not simple and requires careful negotiation of the extent and methods of decolourisation. Cognisance of the reasons why people complain about colour in aquatic environments, is required to ensure that the solution adopted reduces visible colour to a level acceptable to a reasonable person and that the most cost effective method is employed, without causing further hardship to the already depressed textile industry.

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