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# MANAGEMENT OF WATER RESOURCES IN SOUTH AFRICA WITH RESPECT TO THE TEXTILE INDUSTRY

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## ABSTRACT

South Africa is a water scarce country with an average annual rainfall of less than 60% of the world average. It is therefore important to encourage industries to minimise water consumption, and recycle and re-use water and effluent where possible. The South African Department of Water Affairs and Forestry is responsible for the management of water resources in South Africa, thereby ensuring the provision of adequate water supplies of acceptable quality for all recognised users. Of the industrial effluents produced in South Africa, textile effluents are considered to be one of the most problematic in the KwaZulu-Natal coastal area, especially in terms of colour, chemical oxygen demand (COD) and salinity (total dissolved solids, TDS). Of these, colour is perceived to be the most problematic as it is visual pollution and gives rise to public complaints. The Department has been actively involved, through negotiations with management and local authorities, in encouraging the textile industries to reduce the colour load discharged from the factories. Four case studies will be presented describing the approach taken by the Department to solve the problem of textile effluent discharge. © 1997 IAWQ. Published by Elsevier Science Ltd

## KEYWORDS

Colour; case studies; environment; effluent; legislation; pre-treatment; water quality.

## INTRODUCTION

Adequate long term protection of South Africa's water resources is of vital importance for sustained economic growth and development (Department of Water Affairs and Forestry, 1993). South Africa is a semi-arid country in which rainfall and waterbodies are unevenly distributed, both temporally and spatially. The rapidly increasing population and demographic changes have resulted in an expansion in demand which could lead to water becoming increasingly scarce in many parts of South Africa. In addition, greater pollution loads and reduced flows in the country's rivers will place further pressure on the limited resources (Department of Water Affairs and Forestry, 1993).

The Department of Water Affairs and Forestry (DWAF) is the custodian of water resources in South Africa and has the overall responsibility for its management. This custodianship applies to surface and groundwater as well as the coastal marine environment (Department of Water Affairs and Forestry, 1993).



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The hierarchy of the water quality management goals of the DWAF is as follows (Department of Water Affairs and Forestry, 1991) :

- Source reduction, recycling, detoxifying, neutralisation etc. of wastes will be encouraged. Voluntary action is promoted.
- If effluent must be discharged, it must meet the minimum effluent standard which can be either uniform or industry-based.
- If the minimum effluent standards are insufficient to maintain the fitness of the receiving water body, then more stringent standards will be enforced.
- Exemptions for effluent standards will be considered only as a last resort and must be justified on a technological, economical and environmental basis.

Due to the extent and multiplicity of these management functions, the DWAF has adopted, *inter alia*, a participatory management approach to water quality management. The means that the responsibility for water resource management is shared among central, provincial and local government departments, private sector organisations, community-based organisations and non-governmental organisations. Water users and effluent dischargers are also involved in the process of developing and implementing management plans (Department of Water Affairs and Forestry, 1995). Much of the DWAF policy on water management focuses on anticipatory environmental protection, whereby preference is given to controlling the causes of pollution rather than trying to treat the symptoms. This implies that industries are encouraged to reduce emissions to the environment through adopting the best available technology to control pollution and promoting conservation and efficient use of resources.

Uniform effluent standards

Until 1989, water quality in South Africa was managed on the basis of uniform effluent standards which aimed to control the input of pollutants into the water environment by requiring that effluents comply with uniform standards such as the General and Special standards (Department of Water Affairs and Forestry, 1991). These standards were set so as to achieve levels of pollutant concentration that would result from applying *best available technology not entailing excessive cost.* The advantages of this approach are that it is simple and easy to enforce and the standards can be frequently updated to incorporate the newest pollution abatement technology. There are a number of disadvantages to this approach, however, such as:

- it is focused on effluent and effluent treatment and ignores the effect on receiving water bodies;
- there is no incentive for industries to locate at the most environmentally advantageous site; and
- it is not necessarily cost effective as it requires all effluents to comply with the same standards regardless of the cost involved or the impact on the receiving water quality.

This approach was successful in that it retarded the deterioration in water quality, focused attention on pollution and improved effluent treatment. However, the Water Act made provision for exemption from the General Effluent standard. Relaxation of the standards for a specific period could be negotiated, but these were based on technological and economical considerations and did not take into account the impact on the receiving water quality. However, even with these standards, the water quality in South Africa continued to deteriorate and DWAF was forced to re-evaluate its approach to water pollution. For these reasons, the Receiving Water Quality Objectives and Pollution Prevention approaches were introduced.

Receiving water quality objectives approach

This approach takes into account that the receiving water has the ability to assimilate pollution with no notable detriment to the water quality requirements of the recognised users (Department of Water Affairs and Forestry, 1991). This has resulted in:

- the compilation of water quality guidelines based on the requirements of the recognised users;

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- the formulation of water quality management objectives based not only on the requirements of the users, but also on economic, social, political, legal and technological considerations; and
- the imposition of site-specific effluent limits to ensure that the water quality objectives are met for that particular receiving water body.

Fundamental to this approach is a knowledge of the quantity and quality of water required by the different sectors. Five main water users have been identified; i.e. domestic, recreational, industrial, agricultural and natural environment. However, water which might be fit for use in the specific group may not be suitable for another. For this reason, water quality guidelines were compiled for each specific sector.

The advantages of this approach are that both point and non-point sources are taken into consideration, it is cost-effective and it encourages industries to locate in areas where they will have a reduced environmental impact. The disadvantages from a regulatory perspective are that it is technologically more demanding as a knowledge of the chemistry of the pollutants is required, and more detailed investigations are necessary in order to compile a site-specific effluent standard than is required for the special standards.

Pollution prevention approach

This approach is aimed at the handling and disposal of hazardous wastes as toxicity, persistence and capacity for bioaccumulation present major threats to the environment (Department of Water Affairs and Forestry, 1991). It involves source reduction and recycling to reduce the quantity and/or toxicity of waste and to minimise both present and future threats to the environment and public health.

Prosecution

In general, DWAF follows the *polluter pays principle*, whereby polluters are increasingly required to treat their effluents, and undertake and fund monitoring programmes and ecological impact studies to assess the environmental effects of their discharge (Department of Water Affairs and Forestry, 1991).

The Water Act makes provision for the prosecution of offenders that do not comply with its conditions and regulations. The maximum penalty for a first time offender is doubled for a second offence. Additional penalties may be applied if deemed necessary, such as the installation of a specified effluent treatment plant. It has been the DWAF policy not to prosecute offenders immediately, but to aid in a spirit of co-operation. DWAF, however, due to continual deterioration in the quality of the South African water resources, consider pollution as a serious offence and are therefore prosecuting deliberate offenders for a first time offence.

## THE SOUTH AFRICAN TEXTILE INDUSTRY

The South African textile industry is the sixth largest employer in the manufacturing sector, with 80,000 people employed directly, an additional 200,000 indirectly in dependent industries, and supports 80,000 cotton workers. It has local annual sales of R 7.7-billion and is the eleventh largest exporter of manufactured goods. In addition, it is the second largest user of electricity and the second largest payer of rates and taxes in towns and cities across South Africa (Anon, 1994).

Over the past 13 years, the South African textile industry has been in a state of decline and with the lowering of textile tariff rates, the industry is going to become increasingly exposed to international competition over the coming years (Maree, 1995). Therefore, in order for the textile industry to survive it must become more export orientated and economically competitive. However, with the introduction of environmental performance indicators such as ecolabelling and ISO 14000, it is becoming increasingly difficult to export to the European Union and the United States unless textiles are manufactured in accordance with this environmental legislation. Therefore, in addition to this international *trade* pressure, the industry also faces increasing pressure from local authorities to reduce their environmental impact due to the limited water resources within South Africa. Due to the sensitive nature of the industry and the fact that it is a large

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employer in the country, the DWAF has been forced to approach the problem of pollution from the industry in such a manner as to ensure continued operation.

This approach of results through negotiations has been particularly successful in the province of KwaZulu-Natal, where numerous complaints were received concerning pollution in rivers and the marine environment. This paper will present four case studies in this province showing how the DWAF approach resulted in a reduction of pollution from the textile industry.

## ENVIRONMENTAL IMPACT OF TEXTILE EFFLUENTS

Environmental problems in the textile industry are mostly associated with liquid effluent, but solid and hazardous wastes, noise, energy and emissions to air are also of importance. Water consumption and effluent production vary widely from one factory to the next, depending on degree of integration, type of fibre processed, the number of operations, the type of dyestuffs used, the method of dyeing and the type of equipment. Seasonal variations may also affect water intake and effluent quality. The main steps involved in textile processing are: opening, picking and blending; combing and carding; spinning; sizing; weaving; knitting; singeing; desizing; dyeing; printing; scouring; mercerising; bleaching; and finishing. The main types of textile mills include dry processing; woven fabric finishing; knit fabric finishing; wool scouring; wool finishing; stock and yarn dyeing; carpet processing; and contract dyehouses.

The textile industry is a water-intensive industry, and in South Africa the overall water intake in 1993 was $30 \times 10^6$ kl/annum, of which 70 to 80% is returned as industrial effluent. The specific water intake varies from 95 to 400 l/kg fabric depending on the type of processes and water efficiency (Steffen Robertson and Kirsten, 1993).

Dyehouse effluents are complex, containing a wide and varied range of dyes and other products such as dispersants, levelling agents, acids, alkalis, salts and sometimes heavy metals (Laing, 1991). Emissions to water consist of concentrated waste process water, rinsing and cooling water. Rinsing water may represent 60 to 70% of the total water consumption (Swedish Environmental Protection Agency, 1989). The waste water contains natural impurities extracted from the fibres and a mixture of the process chemicals such as organic compounds, dissolved inorganic salts, dyes and heavy metals. In general, the effluent is highly coloured, high in biological oxygen demand (BOD) and chemical oxygen demand (COD), has a high conductivity and is alkaline in nature.

The majority of textile industries in South Africa discharge to sewer and their effluents must therefore comply with limits set by the local authorities, who in turn, must comply with the requirements set by the DWAF. Industries discharging directly to the marine environment must answer to the DWAF. Due to the variable and complex nature of textile effluents, conventional sewage treatment processes often do not sufficiently treat the effluents with the result that colour and other substances (such as salts, solvents etc.) pass through the works and enter the receiving water bodies. Options for effluent treatment and water, chemical and energy recycling have been well researched (Pollution Research Group, 1983, 1987, 1990).

## SOCIAL IMPACT OF TEXTILE EFFLUENTS

The discharge of textile effluent into receiving water bodies without adequate treatment can impact on the lives of the people/communities living alongside the water body. One of the main public concerns with respect to textile effluent is that of colour as it is a visible source of pollution and elicits highly emotive responses from most people. It is not aesthetically pleasing to have a coloured river passing through private property, public recreational areas or in the sea (as in the case of marine discharges). In addition, the majority of the public perceives the presence of colour as being indicative of harmful substances. Colour in rivers may also impact on aquatic life by preventing the penetration of light, thereby interfering with photosynthesis.

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The high conductivity of textile effluents can also have a negative impact. If the salinity of rivers is increased it can prevent the use of this water for agricultural purposes such as irrigation or the watering of cattle. This is particularly of concern in the rural areas where the community life often depends on natural water resources. The presence of solvents is also of concern as they can contaminate, or even kill, aquatic life. This is of particular concern in the marine environment where a fisherman's livelihood could be destroyed.

## TEXTILE INDUSTRIES IN THE KWAZULU-NATAL PROVINCE

There are 24 registered textile companies within KwaZulu-Natal, ranging in size from small (12 staff members) to large (3000 employees). The annual water consumption of these industries varies widely depending on the manufacturing processes used, with an average consumption of approximately 7 500 Ml/annum. This paper will focus on 4 of the industrial areas within KwaZulu-Natal, namely, Pinetown, Hammarsdale, Tongaat and Umzinto (see Figure 1).

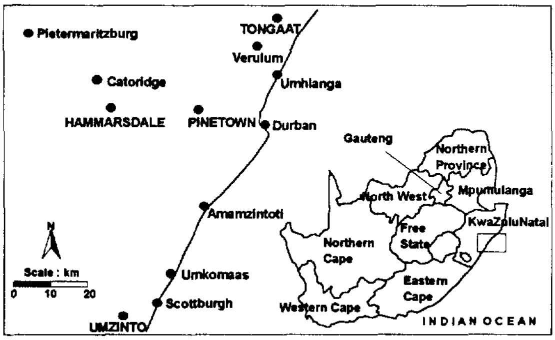


Figure 1. Case studies within the KwaZulu-Natal province of South Africa.

### The Pinetown region

The Umbilo Sewage Purification Works (USPW) in Pinetown discharges treated effluent to the Umbilo River. The works receives both domestic and industrial effluents which includes two large textile companies (processing mostly cellulose-based and polyester fibres) and two smaller companies (one which dyes and prints carpet fibres and the other dyes lace and lingerie fabrics).

During 1988 and 1990, the DWAF received a number of complaints concerning colour in the Umbilo River. The origin of the problem was traced back to the discharge point from the USPW. A colour balance was conducted to determine the source of this colour and it was concluded that it was due to the textile industries discharging to the sewer.

Due to the increasing public pressure and stricter DWAF policies, the Borough of Pinetown was requested to implement steps to reduce the colour in the final effluent by May 1991. As a result, the Colour Committee was convened in May 1990 to consider methods of solving the problem of colour in the Umbilo River. It was comprised of representatives from the local textile industries, the Borough of Pinetown, the University of Natal (through the Pollution Research Group), the South African Water Research Commission, and was chaired by the DWAF.

The committee met for 4 years, during which time there was intensive negotiations between the DWAF, the USPW and the local textile industries to find a solution to the colour problem. Originally, the target colour standard for the USPW discharge was suggested by DWAF at 80 Hazen units (approximately 80 ADMI) which meant that a 70% colour removal was necessary on-site. In May 1994, it was decided that a limit of 400 ADMI colour units be set for factory discharge to sewer and the DWAF issued a statement that *the final*

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*effluent colour (from the Umbilo Sewage Purification Works) should be such that it does not give rise to public complaints and effluent leaving dyehouses should be such that its contribution to the Umbilo Sewage Purification Works does not cause the colour of the final effluent to be visually displeasing.*

Based on this decision, a consultant was appointed to undertake studies into the most effective on-site effluent treatment system for the Pinetown textile industry. Two suitable techniques for removing colour from textile effluents were identified and the respective costs of treatment to the factories were calculated. Based on in-depth laboratory tests, it was decided that the use of Fenton's Reagent (Kuo, 1992; Rupert *et al.*, 1993) was the more appropriate as it was effective in removing colour from a wide range of dyes, the presence of iron ions was beneficial to the operation of the sewage works, it was simple to operate and had low capital and operating costs. A treatment plant was established at a factory in Pinetown (which did not discharge to the USPW) and monitored closely over an 8 month period.

Based on the success of this study, similar treatment plants were commissioned at the two larger factories in 1994 and 1995. Unfortunately, the effect of these plants on the colour in the Umbilo River is difficult to assess due to the excessive rainfall received in the months following the commissioning of the plants (1995 and 1996), but it is anticipated that the situation will improve.

The most important aspect of this case study is that the formation of the Colour Committee was successful in bringing about co-operation between the textile industry and the local authorities resulting in a commitment by both parties to resolve the problem of removing the colour in the Umbilo River.

During this period, experiments were also conducted into the feasibility of using anaerobic digestion to decolourise textile effluents. A full-scale trial was conducted at the USPW where concentrated reactive dyebath effluent was trucked on a daily basis to the works and discharged into one of the primary anaerobic sludge digesters (Carliell *et al.*, 1996). The overflow from the digester was monitored for colour and to determine the effect of this effluent on digester performance. This work was carried out over a 5-month period in 1994 by the Pollution Research Group and had the backing of the DWAF as it presented a possible further solution to the colour problem in the Umbilo River. The results of the trial were promising, with no colour being present in the overflow from the digester. An increase in the sodium and sulphide concentration in the overflow was noted however, due to the sodium sulphate used in the reactive dyeing process, but these concentrations never reached a point where digester instability was threatened. It was felt that although this treatment route showed promise, the transport costs were inhibitory and there was insufficient information available on the long term effect of the textile effluent on the digester performance.

### The Hammarsdale region

The Hammarsdale Waste Water Treatment Works (HWWTW) receives approximately 65% of its flow from textile industries. Of the balance, 25% is from a chicken abattoir and 10% from domestic sources. The HWWTW discharges effluent into the Sterkspruit river in the Shongweni catchment area. The works is managed by Umgeni Water and the final effluent from this works must comply with standards set by the DWAF. Due to the predominantly industrial nature of the influent to the works, the required standards for certain variables were not met and the DWAF granted the works relaxations until March 1989. In 1990, however, the DWAF notified the works that any requests for further exemptions would be subject to a *receiving water quality objectives* study and the determination of acceptable receiving water quality objectives. Based on this requirement, a *receiving water quality objective* report was prepared by Umgeni Water for the Sterkspruit/Shongweni system to identify determinants in the final effluent from the works which were not complying with standards set by the DWAF. These included high conductivity and colour (Umgeni Water, 1994).

The major water users in the system were identified to be aquatic life and recreation, both of which are not impacted upon by high conductivity, although aquatic organisms can be affected by sudden changes in conductivity. Conductivity limits, as set by the DWAF for potable water users, are not met for 95% of the time, but the Sterkspruit river is not used as a potable water source. However, the high conductivity of the

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water in the river renders it unsuitable for irrigation. Although irrigation was not identified as a major down-stream water user, the DWAF is under pressure from the local communities that rely on the Sterkspruit for watering their crops and cattle. The colour in the final effluent for the works impacts heavily on the colour in the Sterkspruit River and does not comply with the recreational limits. This leads to complaints due to aesthetic reasons.

The DWAF, together with Umgeni Water, identified a number of action plans to overcome these problems. Success is being achieved through the encouragement of the local textile industries to carry out pollution prevention programmes within the factories to reduce the concentration of chemicals discharged to sewer. In addition, the DWAF supports the research currently being conducted by the Pollution Research Group into the modification of the works so as to achieve greater colour removal. It was also recommended that annual assessments be carried out in the catchment area to determine the effects of these programmes and whether there has been any changes in the demands from down-stream water users.

The Tongaat region

A large textile finishing company situated in Tongaat discharges its effluent directly to sea via a pipeline which lies at a depth of approximately 1 m at low water tide and a distance of approximately 200 m off-shore. As the local municipality is not responsible for marine discharges, the company has to answer directly to the DWAF. Over the years, the DWAF has received numerous public complaints regarding colour in the sea due to the effluent from this factory and also reports that the fish are contaminated with the taste of solvents. In addition, any blockages or leaks in the pipeline causes effluent to be discharged into the Tongaat River which results in the death of aquatic life. The solvent (white spirits) in the effluent was due to the large amount of printing that was carried out by the factory. The factory was informed by the DWAF that no solvent was to be discharged to sea and that an alternative solution must be found. This resulted in the factory replacing all solvents by an aqueous printing system which has been shown to produce goods of similar quality.

The company were also informed of impending action by the DWAF if the colour in the effluent was not decreased to the extent that it would not impact negatively on the beneficial users. This was achieved through the extension of the pipeline and in-house colour minimisation, and the factory is now in the process of installing an effluent treatment plant (flocculation followed by dissolved air flotation) to treat the highly coloured effluent streams. The non-coloured water, such as that from rinsing, is still to be discharged directly to sea.

The Umzinto region

Originally, the effluent from the local sewage works in Umzinto discharged its final effluent into the river upstream from the abstraction point for the water supply for the coastal holiday town of Scottburgh. The works received effluent from 2 large textile mills and was unable to sufficiently treat this complex effluent, with the result that the colour passed through the works and ultimately discoloured the drinking water of Scottburgh. These factories were put under pressure by DWAF to treat their effluents.

This resulted in the installation of a reverse osmosis plant at the one factory which allowed for removal of colour and reuse of water within the factory (Groves *et al.*, 1983) and the concentrates were trucked to a deep marine pipeline 10 km away. In addition, the factory financed the relocation of the drinking water abstraction point to a point upstream from the final effluent discharge from the sewage works. However, due to flood damage, this abstraction point was destroyed and never replaced, resulting once more in the presence of colour in the drinking water supply.

This area has also been subjected to severe droughts with the result that strict limits on water use were set for the factories and there was increasing pressure on the factories to reduce colour in the effluent as the river could not accommodate the colour load during such a low flow period. As a result, this factory has

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installed a flocculation plant to remove colour from the effluent before being sent to the reverse osmosis plant. It is planned that 100% water reuse within the factory will be achieved.

The second textile factory, through negotiations with DWAF, are currently in the process of installing a colour removal plant to further decrease the colour load discharged to the sewage works.

## CONCLUSIONS

The effective management of water resources in South Africa is essential for sustained growth and development of the country. This responsibility is carried by the DWAF. The introduction of the *receiving water quality objectives* approach and the *pollution prevention* approach have aided in reducing the deterioration of the water resources within South Africa. Of the industries operating in South Africa, the textile industry is considered to be one of the most polluting as the effluents are generally highly coloured, have a high COD and a high conductivity. These effluents have both an environmental and social impact. The DWAF has been actively involved in reducing the impact of these effluents in the province of KwaZulu-Natal, and in particular the Pinetown, Hammarsdale, Tongaat and Umzinto areas. In all 4 cases, results were obtained through continual negotiations with the industries rather than through the enforcement of penalties.

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