REVIEW OF POLLUTION PREVENTION CONTROL TECHNOLOGY IN THE TEXTILE INDUSTRY

United States of America
April 23 - May 6, 1994

Prepared for:

US - ASIA ENVIRONMENTAL PARTNERSHIP

WORLD ENVIRONMENT CENTER

DISCLAIMER

This project was sponsored by the U.S. Agency for International Development (USAID) through the World Environment Center's (WEC) Cooperative Agreement in support of the U.S.-Asia Environmental Partnership (US-AEP). The opinions expressed herein are the professional opinions of the author and do not represent the official position of the Government of the United States of America or the World Environment Center.

TABLE OF CONTENTS

APPENDICES

I. EXECUTIVE SUMMARY

An Environmental Business Exchange (EBE) was conducted for representatives of the Indian textile industry from April 23, 1994 to May 7, 1994 to familiarize them with the textile operations, new manufacturing equipment, process control, and pollution control technologies in the U.S. The exchange focussed on the following areas:

- wastewater treatment and design overview;
- solid waste treatment and disposal;
- eco-friendly chemicals, dyes, and processes;
- chemical use and containment considerations; and
- health and safety considerations.

The exchange included the participation of two distinct groups from the Indian textile industry.

The first group of exchange participants consisted of industrialists from small-scale textile processing, dyeing, and printing units in Jodhpur and Balotra in the state of Rajasthan.

Amrit Raj Dhariwal
Mangal Textiles
F-3-4 Basni 2nd Phase
Jodhpur
342-005 Rajasthan, India

Gautam Chopra
Balotra Laghu Udhyog Mandal
F-115, Industrial State
Balotra, Rajasthan, India

M.I. Daga
M- Processing House Pvt Ltd
E-224, Industrial Area
Balotra, Rajasthan, India

G. M. Singhvi
Kiran Textiles
17-C Heavy Industrial Are
Jodhpur - 342-001, India

The second group of participants consisted of textile technocrats from Surat in the state of Gujarat. Surat is the largest synthetic industrial center in India.

Vikram Singh Rathore
Small Industries Development Bank of India (SIDBI)
Andand Bhawan
Sansar Chandra Road
Jaipur - 302001, India

Chattaran Desai
Technical Director
Paradise Prints
Desai Street, Sagrampura
Surat 395 002, India

Girish R. Luthra
Technical Director
Luthra Dying and Printing Mills
Pandesara, Surat
394-221, India

Bapu Deshapende
Senior Executive
Technical Service, Product Development
Bhavin Textiles, Colourex
GIDC, Pandesara
Surat 394 221, India

The tour in the United States was conducted by WEC and Winston C. Boteler, WEC consultant and Emeritus Professor of Textile Engineering at the Georgia Institute of Technology.

The observations and findings of the study tour are presented under the following sub-headings:

- Environmental Protection Laws, and Administration;
- Research and development in environmental protection technologies;
- Facilities for the treatment of effluent wastewater and textile processing units visited;
- Textile processing machinery technologies.

Funding for this project was provided through a Cooperative Agreement between the World Environment Center (WEC) and the United States-Asia Environmental Partnership (US-AEP).

II. INTRODUCTION

From April 23, 1994 to May 7, 1994 the eight member delegation, composed of individuals representing various sectors of the Indian textile industry visited the U.S. This diversification allowed different aspects of textile processing, ranging from the technical to the economic, to be taken into consideration.

To gain an understanding of the laws and regulations applicable to wastewater effluent treatment from textile facilities, the group visited the Alabama Department of Environment Management (ADEM). ADEM was established under the implementing environmental laws in Alabama. It administers all major federal environmental laws, including the Clean Air Act, Clean Water act, Safe Drinking Water Act, and federal solid and hazardous waste laws.

In order to gain insight on wastewater treatment the delegation met with institutions that have carried out extensive research and development (R&D) work in the minimization, reduction and treatment of textile waste. Specifically, they are the North Carolina State University (NCSU) Textile Department and the Institute of Textile Technology (ITT). To date, the treatment of both sewage and industrial wastewater remains to be the major issue surrounding the Indian textile industry to which a feasible solution has yet to be developed. In conjunction with these meetings, the delegation visited the Westpoint Stevens Incorporated facilities and the Burlington Industries Incorporated facilities to observe specific technologies being implemented for textile wastewater. A third treatment facility, the Sugar Creek Wastewater Treatment Plant, which deals with municipal as well as industrial wastewater was also toured.

Another aspect of textile manufacture that influences pollution production is the processing of the textile itself. In this respect several private companies, namely the Gaston County Dyeing Machine Company, Strandburg Engineering Laboratory Incorporated, Tubular Textile Machinery, SheLyn Incorporated and the Hunter Associates Laboratory, were all able to provide the delegation with a general idea of the textile machinery currently being employed in the U.S.

It was found that protection of the environment from textile waste discharge can be addressed at several points in processing beginning with regulations to uphold environmental standards, wastewater minimization and treatment as well as the adaptation of specific technologies applicable to the Indian setting for clean and efficient textile processing. Specifically, the delegation agreed that while the "activated sludge technology" is still a common treatment method for municipal wastewater, the "extended aeration activated sludge" and "aeration lagoon" systems based on aerobic treatment of the wastewater appears to be appropriate for the treatment of textile waste in India. Aside from the fact that it has proven to be quite

successful, it is also cost effective, easy to operate, and flexible in nature, so that it is adaptable to particular conditions prevalent in India. With regard to waste control at the processing level, present-day technology for textile manufacture in the U.S. is highly advanced being largely automated and having built-in computer systems for control monitoring and corrective action. However, such sophistication may not be feasible in the Indian setting due to variability in the availability of a highly skilled technical work force as well as in environmental conditions which are likely to adversely affect the machinery.

III. FINDINGS

1. ENVIRONMENTAL PROTECTION LAWS AND ADMINISTRATION:

The U.S. Environmental Protection Agency (EPA) formulates rules, regulations, and standards for the protection of the environment from air, water, and land pollutants. EPA delegates the authority to implement federal environmental statutes to the states, provided they have laws and regulations equivalent to federal standards, and matching funds and personnel to administer the programs. The State of Alabama's Department of Environmental Management (ADEM) was established under the Alabama Environment Management Act of 1982 and is responsible for implementing environmental laws. It administers all major federal environmental laws, including the Clean Air Act, Clean Water Act, Safe Drinking Water Act, and federal solid and hazardous waste laws.

Alabama is very rich in water resources and ranks seventh in stream miles, fourteenth in lakes, and twenty-fourth in wetlands in the U.S. In view of this, ADEM is all the more conscious of minimizing water pollution by effective regulation so that these invaluable water resource do not get polluted. ADEM evaluates and classifies all waters on the basis of existing and expected uses. Currently, more than 99 percent of the state's waters maintain at least a fish and wildlife water-use classification, which is the goal of the Clean Water Act. These standards are achieved and maintained by regulating point source discharges, including municipal sewage treatment plants and industrial facilities. Alabama also regulates non-point source discharges, including agricultural and construction activities and urban run-off.

ADEM issues permits requiring, at a minimum, that industries meet best available technology standards, and that municipal and private permittees provide secondary wastewater treatment. Many point source dischargers must also conduct tests to ensure that effluents do not contain pollutants at levels toxic to aquatic life. ADEM administers the national permitting system for wastewater discharge and there are four options for the disposal of industrial wastewater:

a) *Direct Discharge* - for which a National Pollutant Discharge Elimination System (NPDES) permit is required. This permit prescribes stream water quality standards for treatment before discharge.

b) *Indirect Discharge* - for which a State Indirect Discharge (SID) permit is required for all significant industrial discharges to Publicly Owned Treatment Works (POTWs), or other wastewater treatment facilities. This places responsibility for pretreatment regulation at the state or local level.

c) *Subsurface Discharge* - requires an Underground Injection Control (UIC)

permit, with conditions based on groundwater drinking water standards.

d) *Zero Discharge* - for which no permit is required since there is total recycling/reuse of process wastewater with zero discharge.

ADEM's effectiveness in issuing permits that protect water quality is checked by conducting intensive studies of rivers and streams to ensure that discharges do not adversely affect water quality. Despite great progress in reducing pollution from industrial and municipal sources, water quality goals are, in many instances, still impeded by non-point source pollution. The ever increasing pollution problem related to stormwater from non-point sources has been attracting greater attention from the authorities during recent years. General permits were recently authorized by EPA and developed by ADEM. As a result, ADEM is now requiring thousands of facilities not previously regulated, ranging from transportation terminals to salvage and recycling centers, to implement measures to prevent run-off of contaminated stormwater.

While environment protection for water is administered by ADEM's Water Division, the Air and Land Divisions manage environment protection with respect to air and land pollution from solid and hazardous waste. ADEM also administers the State Revolving Fund which provides low-interest loans for municipal sewage projects.

2. RESEARCH AND DEVELOPMENTS IN ENVIRONMENTAL PROTECTION TECHNOLOGIES:

a. The Tennessee Valley Authority's (TVA) environmental research center in Muscle Shoals, Alabama, is engaged in research in developing and transferring new technologies to combat degradation of water, air, land and other natural resources. The center has state-of-the-art laboratories, composting facilities, greenhouses, and the nation's leading constructed wetlands research and development facility. The major focus of the center's work is developing waste management systems that offer practical solutions to critical environmental problems.

The biotechnology division is investigating biotechnical processes making use of bacteria or fungi to detoxify or neutralize problem wastes with specific focus on:

-- Developing better waste-handling options;
-- Creating useful products, thereby conserving valuable resources;
-- Reducing the emissions of gases that contribute to global climate changes.

Another approach involves use of a constructed wetland for wastewater treatment. The constructed wetlands at Muscle Shoals were visited and Mr.

Peter Burgoon, Research Engineer, provided information on simulations of swamps to filter and treat contaminants in the wastewater and utilize the treated wastewater for growing plantations on gravel beds with the use of nutrient solution. The plants being grown are fragmites (common reed), communins (genus species), and typha (cactus).

It is worthwhile to note that the Central Arid Zone Research Institute (CAZRI) at Jodphur, India, was also undertaking similar research and development on the utilization of textile wastewater after preliminary treatment for growing different kinds of plants/vegetation. An exchange of information between the two organizations could be very useful in this field. The following suggestions were made by the delegation:

i) In addition to the experimentation on gravel-bed, experimentation on soil could also be carried out.

ii) Experimentation should be conducted on growing plants having commercial value, including both food and non-food crops.

Mr. Burgoon further informed the delegation that the water pollution problem was more acute in the case of non-point source discharges which include agricultural and construction activities, and other run-offs. Non-point source pollution is water pollution which does not come from any specific point or location. Rainfall run-off carries soil, pesticides, and other domestic residues into waterways. The net effect is a release of dirt, trash, nutrients, and other pollutants that produce more water pollution than all of the sewage and industrial plants. While point source pollution is widely regulated by federal, state, and local agencies, there are relatively few laws that control non-point source pollution, which accounts for 73 percent of the present water pollution in the U.S. according to EPA reports. For non-point sources, prevention may be less expensive than subsequent treatment and, as such, control must begin with individuals.

b. A special project developed in conjunction with the TVA is the State of Alabama's innovative **Waste Reduction And Technology Transfer Program (WRATT)** which uses the expertise of retired engineers and scientists to provide waste reduction opportunity assessments to industries in Alabama. This idea of utilizing retired engineers/scientists and initial training/orientation of these retirees was developed and funded by TVA. Mr. Roy Nicholson, Chief Operating Officer of WRATT, informed the delegates that the foundation is a non-profit corporation staffed by dedicated retired engineers and scientists with extensive industrial experience in waste reduction and pollution control. The foundation's mission is to provide technical assistance to industry by on-site

waste reduction assessments and reports with additional focus on training/reduction and research needs. The foundation provides free, confidential and non-regulatory waste reduction assessments to public and private enterprises on request. Each operation is reviewed for potential waste reduction strategies and opportunities including source reduction, reuse, recycling, energy recovery and waste treatment.

The foundation also works for promoting and encouraging awareness for waste reduction and also educates public and private business enterprises in this field. It conducts, encourages, and assists research to further the cause of waste reduction and pollution prevention. WRATT has already performed over 140 assessments. It has served different types of industry in reducing waste, which mainly include chemicals, metals, wood, textiles, paints, plastics, and paper industries. The WRATT program has been used as a model for organizing similar programs by other states.

c. **The North Carolina State University** has ten colleges in various disciplines with about 24,000 students enrolled. The University's College of Textiles is the largest Textiles College in the U.S. It has one of the most integrated programs for textile education in the world, and facilities for reduction, research, and extension services to the textile sector in North Carolina. The budget for research activity during the current year is US $10 million.

Professor Brent Smith, Associate Professor (Textile Chemistry) gave an overview of the problems of environmental pollution created by textile processing operations which generate high volumes of wastewater of varied composition containing salts, organic surfactants, solvents, and dyes. Removal of salts and color is difficult, and dyes are a highly dispersible pollutant which contribute to aquatic toxicity. They are difficult to treat and interfere with municipal waste treatment operations, (i.e., ultraviolet light disinfection processes which are popular replacements for chlorination). Commercial dyes are usually mixtures of large complex and often uncertain molecular structure and properties. Color pollution is most efficiently controlled by good source reduction practices based on administrative and engineering controls, process and product design, and work practices. The use of iron-based dyes instead of chrome/cobalt based dyes is recommended as the former are non-mutagenic and non-toxic. No single technique is likely to solve all problems, especially in the area of color pollution control.

Research has been conducted on decolorizing dye wastewater by using "chitosan" (a bio-polymer obtained from crabshells) as a solid absorbent. Due to its unique molecular structure, chitosan has an extremely high affinity for many classes of dyes, including disperse, direct, reactive, acid, vat, sulfur and

naphthol. Chitosan also has versatility in terms of its ability to absorb metals and surfactants. However, textile wastewater contains many other substances. Therefore, further work in elucidating the effects of salts, surfactants, textile auxiliary, absorbent and dye interactions is needed. No single decolorization method is likely to be optimum for all wastewater streams.

The problem of textile wastewater has gained momentous proportions and an estimated 600,000 tons of hazardous waste is generated in the U.S. from the textile processing units which is being adequately treated and goes down common drains in the absence of an alternative solution. The textile industry's continuing concern for the environment and desire to be better corporate citizens has brought renewed emphasis on environmentally friendly products and production, using technologies that focus on either source reduction or improved waste treatment.

Mr. Smith concluded by stating that the waste reduction/treatment technologies can be divided into 5 categories starting from the simpler existing technologies followed by proven technologies not in use, developing technologies, unknown technologies to reduce waste and outside waste processing technologies. He was of the opinion that instead of waiting for advanced research to develop optimum technologies, the practical approach lies in the textile industry adopting and implementing the best available techniques and technologies to minimize waste. It is more practical to effectively implement the simpler and known measures rather than wait for, or move directly on to, research and high risk areas.

d. **American Association of Textile Chemists & Colorists (AATCC)**, (North Carolina) was set up in 1921 along the lines of the Society of Colorists and Dyers in Europe. The members of the association represent textile mills, dye-houses, chemical suppliers, dye manufacturers, commercial laboratories, consumers and retail organizations, state and federal government agencies and educational institutions. The objective of AATCC is to undertake and encourage research work on chemical processes and materials of importance to the textile industry. It also endeavors to promote increased knowledge of the application of dyes and chemicals in the textile industries, and to establish for its members channels by which an exchange of professional knowledge may be increased.

The AATCC also coordinates, assembles, and disseminates information for the advancement of textile science and technology through organizing/sponsoring seminars, symposia, workshops, and study groups at the national and local levels A color index manual containing technical details about various colors and dyes, which is periodically updated, has also been published by the AATCC. AATCC is internationally recognized for its standard methods and

equipment for testing dyed and chemically treated fibers and fabrics to measure such performance characteristics as color fastness to light washing, durable press, soil release, shrinkage, water resistance, flammability and the many other conditions to which textiles could be subjected.

The members of the textile delegation showed interest in becoming members of AATCC so as to gain from the services being extended by the association in various aspects of color and wet processing of textiles.

e. **The Institute of Textile Technology (ITT), Charlottesville, Virginia,** is a non-profit educational and research organization dedicated to the excellence of the american textile manufacturing industry. ITT undertakes research work on manufacturing facilities in the textile sector with emphasis on applied research having practical utility. Mr. Mac Creight, Vice President, informed the study tour participants that the institute is funded by member industrial units and its goals are to act as a focal point of excellence in leadership in textile technology, select and develop graduate student to assume management/leadership roles in the textile industry, and to develop a textile technology data base. For this purpose, the Institute brings out a monthly textile technology digest which contains abstracts selected from over 400 periodical titles as well as other material from the Institute library collection which is supposed to be the largest repository of specialized textile information. Since 1978, the abstracts have been stored in a data base and can now be retrieved directly on any IBM or compatible computer with a compact disk (CD-ROM) drive. This data base has proven to be a valuable resource world wide for manufacturers and educational institutions directly or indirectly connected with the textile industry.

The Institute's technology transfer center at Spartanburg, South Carolina, has started the Textile Resource Conservation (TReC) Project which is a multi-task research effort designed to recover and reuse valuable raw materials in the integrated textile industry. This is the largest environmental research project ever undertaken by the integrated textile industry focussing on waste minimization. The goal of the TReC project is producing high quality textile products with reduced environmental impacts.

Mr. Michael S. Bahorsky informed the delegation that the U.S. Environmental Protection Agency (EPA) had, since the 1960's, propagated and advocated the use of advanced wastewater treatment technologies like carbon tube, reverse osmosis, ozone coagulation, etc., which were complicated and costly, and therefore, difficult to implement by the textile sector in general. As far back as 1972, ITT had advocated the biological treatment for textile wastewater which was appropriate and cost effective compared to these advanced technologies and has been effectively implemented. It is still in use for more than two

decades. The technology is similar to that used for the treatment of municipal wastewater.

Mr. Bahorsky felt that there is need for a cooperative agenda for tackling wastewater problems, including all concerned agencies. The cooperative agenda advocated by ITT emphasizes that legislation and regulation are not the solution to the issue, rather, it is the education of the textile sector towards this problem and, implementing and developing wastewater treatment technologies in a cooperative spirit rather than as a response to legislation.

The activated sludge technology is suitable for treatment of municipal waste and the period of retention required is about 8-10 hours. However, for treatment of textile waste, the 'extended aeration activated sludge technology' is more suitable where the retention period required is 3-4 days. In the field of textile wastewater, the latest technology being considered is the "sequencing batch reactors" (SBR) technique, which has the special feature of eliminating clarifiers, reducing pumping and piping, use of less space, better control, and of being highly automated and flexible. The SBR technique involves anaerobic bacterial treatment and the treated water is used for irrigation and growth of grass/aquatic vegetation such as bulrush, cattail, etc. A combination of aerobic and anaerobic treatment may be more effective in treatment of dyes and removal of color, but may be quite costly. Further details about SBR techniques were not available at the institute, and Mr. Bahorsky suggested Aqua Aerobic at Rockford, Illinois, for obtaining further details about this technology.

3. FACILITIES FOR TREATMENT OF EFFLUENT WASTEWATER AND TEXTILE PROCESSING UNITS VISITED:

The delegation visited the wastewater treatment facilities at the following centers:

(i) Westpoint Stevens Incorporated, Opelika Finishing Plant, Opelika, Alabama
(ii) Burlington Industries Incorporated, Wake Plant, Raleigh, North Carolina
(iii) Sugar Creek Wastewater Treatment Plant, Charlotte, North Carolina

While facilities at Westpoint Stevens Incorporated, Opelika Finishing Plant, Opelika, Alabama and Burlington Industries Incorporated, Wake Plant, Raleigh, North Carolina are plants for the treatment of textile wastewater, the facility at Sugar Creek Wastewater Treatment Plant, Charlotte, North Carolina is for the treatment of a combination of municipal as well as industrial wastewater. Observations on these three facilities, along with two other textile processing units visited, are presented below.

a. **Westpoint Stevens** is the largest manufacturer and marketer of bed and bath textiles. The wastewater treatment plant at the **Opelika Finishing Unit** in Alabama has a capacity to treat 13 million gallons per day (mgd) of textile wastewater. The company manufactures polyester as well as cotton based products and generally uses vat and disperse dyes. In the initial years, a plant based on activated sludge technology was built, but this was found to be inadequate and not suitable as the treated water did not meet the EPA standards. Also, the plant was not able to cope with the increased volume of the effluent wastewater resulting from increased operations. The disposal of sludge also posed a problem. Therefore, the company modified the system of treatment from time to time and finally switched to treatment based on aerated lagoons. Further improvements were introduced by converting one of the aeration basin to an equalization basin (depth - 15 feet; retention period - 1 1/2 days), introduction of a bar screen followed by a lint screen at the entry point so as to separate solid waste Lateron, addition of silicate to the textile effluent discharge at the initial stage was also introduced so as to reduce concentration and the pH level was also brought down from 12 to around 7-8 by the use of soda ash and alum.

The treatment system was further improved by the introduction of mixer/flocculators (depth - 10 feet; retention period - 1 day) where polymer coagulants were added for better flocculation. The water is then passed through clarifiers (depth - 10 feet) where sludge is collected and the residual liquid at the top is repumped to an aeration basin (depth - 10 feet; retention period - 2 days) and then passed through decanters. The sludge collected at the clarifiers is passed through an aerobic digester (retention period - 6 days) where air is passed through the sludge by blowers. The digested sludge is then passed through thickeners, and finally through the sludge press where remaining water is removed to the maximum extent possible and the solid sludge is collected for final disposal in landfills. The water from the aeration basin is passed on to decanters from where it passes on to the polishing pond and finally to the post aeration basin where residual solids, if any, settle down and the treated water is discharged into the stream.

The Westpoint Stevens Plant has also introduced the following in-plant measures for waste minimization:

(i) Reduction in the quantity of water used to the minimum;
(ii) Recycling of water and use of counter-current system;
(iii) Controlling levels of dyes used;
(iv) Caustic recovery, discharge of only 2 percent.

With the above in-plant measures and the effluent treatment plant, the Opelika Finishing Plant at the Westpoint Stevens has been successful in minimization

and treatment of textile wastewater.

b. **The Wake Plant of the Burlington Industries Incorporated** is engaged in printing and dyeing of textile knit wear. It has a capacity of processing 800,000 pounds of cloth (100 percent cotton and polyester blends) per week. The plant has the latest modern machines having 4 continuous bleach ranges, computerized jet dye system and computerized color mixing equipments.

The working of the wastewater treatment plant having a capacity of 5 mgd was explained by Mr. Tim Holland, Manager (Engineering Department). The technology utilized is based on 'extended aeration activated sludge.' The treatment plant has bar screen followed by equalization basin (retention period - 6 hours), 2 aeration beds (depth 10-12 feet, retention period - 1 day); 2 clarifiers and finally the aerobic digesters. At the clarifiers stage the use of ferrum sulphate and alum sulphate for color reduction was tried but was later discontinued as it was not very effective and also resulted in an increased volume of sludge. From the digesters, the sludge is separated and held in drying beds for 7 - 10 days while the water is pumped to the filtration pond before being discharged into the drains.

The following chart gives the characteristics of the wastewater before and after treatment:

Parameters	Range	
	Before Treatment	**After Treatment**
BOD	160 - 175	4 - 10
COD	600 - 1100	100
pH	10 - 10.5	8

As far as removal of color is concerned, no additional treatment is being done and the process of oxidation helps to reduce color by about 50 percent. The plant does not use any chemicals in the treatment process; even pH is reduced by the natural process of oxidation in the course of aeration. The only chemicals used are polymers for the coagulation of sludge.

c. **The Sugar Creek Wastewater Treatment Plant** provides municipal wastewater treatment for the City of Charlotte, North Carolina. The plant is a combination of activated sludge and aerobic treatment. At the time of the visit, the inflow of wastewater (a combination of municipal - 80 percent, and industrial - 20 percent) was around 10 mgd. The treatment begins with screening at which stage hydrogen peroxide is also added as a deodorizer. After screening, the wastewater goes to four clarifiers for primary treatment and solids settling, then to the digesters. The solids are broken by bacterial action in the digesters and the water from there is taken to the trickling filters. An aerated activated sludge system is used for secondary treatment. The wastewater goes to large 20 foot deep cement tanks where aeration is provided by pumping air through diffusors at the bottom of the tanks. Wastewater retention time is approximately 8 hours. The wastewater is then sent to four secondary clarifiers, and then to the aeration lagoon for further sedimentation. Finally, the water is discharged into the stream after chlorination. The present capacity of the treatment plant is 14 mgd and there are plans to upscale it to a capacity of 20 mgd.

d. **Teejays Textile Mills** at Florence, Alabama, has a capacity to manufacture 15,000 cases of T-shirts per day and employs approximately 1,600 people. It is a composite mill engaged in weaving (cotton-polyester knits), dyeing, bleaching and finishing of knitted cloth, and final fabrication of the T-shirts. Taiwan-made circular looms are used for knitting, while low pressure jet dyeing machines are used for dyeing. Approximately 500,000 gallons of water is used

to process 75,000 pounds of cloth daily. The company has a well-equipped modern color mixing and testing laboratory and has recently introduced the latest infra heating sample dye machine.

The unit does not have a wastewater treatment plant of its own, and has installed only a centrifuge pump where solids are separated by filtration in a vibration vessel. The wastewater is then discharged to the city drains for further treatment by the City of Florence sewage treatment plant. Treatment charges are recovered from the company.

e. **The J.P. Textiles Associates** in Forest City, North Carolina, is engaged in wet processing of knitted fabrics (90 percent cotton). It is engaged in bleaching and dyeing on a commission basis, and is equipped with modern machines (an aggregate investment of about US$5 million. In particular, a continuous bleaching machine, a mercerizing machine, and a dyeing machine. The company has not set up any wastewater treatment plant, and it discharges wastewater (2.5 mgd to the municipal collection system. The water is treated by the City's wastewater treatment plant and the company is charged for treatment.

f. **Health and Safety Measures for Workers:**

The textile industry uses hazardous chemicals, mainly color and dye stuffs. In all the facilities visited, the delegates observed that special measures are taken to ensure worker health and safety. The chemicals used are classified and stored as per requirements specified by the EPA and health codes based on degree of hazardous nature of the chemicals degree of flammability, degree of reactivity. Codes for personal protection are very clearly indicated on all storage containers. Wherever necessary, workers are provided with safety equipment such as masks, gloves, boots, eye glasses, etc., so as to ensure full safety and protection of the workers.

4. TEXTILE PROCESSING MACHINERY AND TECHNOLOGIES

The following sections provide an account of the companies visited to obtain an idea of the present technology used for the manufacture of textile machinery in general, and the technology and equipment for minimization/treatment of wastewater effluents from textile units.

a. **The Gaston County Dyeing Machine Company**, which started as a family owned company in 1921, is a manufacturer and world leader in the development of textile wet processing machinery and associated electronic control systems. The knowledge gained by the company during its more than 70 years existence makes it a company which thoroughly understands the dyeing processes. It is the most experienced manufacturer in designing dye-house management control systems for efficient machine operations. The company's machinery and equipment serves about 95 percent of the domestic textile dyeing systems and it has installations in more than 80 countries around the world. However, its major sales are within the U.S.; exports account for about 15-20 percent of total sales.

Processing Machinery:

The company has worked closely with dye-house managers and plant-engineers in order to satisfy the total needs of the wet processing industry. It has a long term well funded research and development program which enables to maintain its position as a world leader in the development of new process and technology for bleaching, dyeing and wet finishing of fibre, yarn and fabric.

Gaston County has a wide range of piece dyeing machines which are available in high pressure or atmospheric designs and are suitable for volume processing of soft, spun yarn, knit and woven fabrics, as well as fabrics using filament yarns. The machines are designed for a short cycle and low liquor-to-cloth ratio processing and the range of fiber and yarn dyeing machines includes yarn breakage dyeing machines, raw stock dyeing systems, and yarn beam dyeing machines. The dye-house management and control systems developed by the company make use of improved computer technology so as to optimize the dyeing process for high efficiency with minimum consumption of utilities, chemicals, and dyes and input as also to offer a comprehensive selection of management reports. The range of process control equipment includes a micro-computer based process control system which is capable of creating, editing and storing dyeing procedures and other process parameters.

A complete range of sub-programs is available to help increase productivity, reduce quality problems, eliminate operator errors and reduce dye and chemical costs.

The continuous range equipment of the company includes the rope bleach range equipment which is a continuous bleaching range for most cost effective bleaching of cotton and cotton-polyester blends. The knit goods bleach range is designed for high quality bleaching of cotton and polyester/cotton knits and towel fabrics without distortion or crushing. All of these ranges are available with an automatic chemical feed system, comprehensive control instrumentation and related auxiliary equipment. The laboratory equipment manufactured by the company includes the lab dye and chemical tester which provides a standard, repeatable method for evaluating, under controlled conditions, properties like foaming, filtration, dispersion, and chemical compatibility characteristic of dyes and auxiliaries. The laboratory package dyeing machine and laboratory extractor/drier enables dyeing extraction and drying of sample packages.

Environmental Protection:

Gaston County is also very keen on environmental protection and its machines have been designed for low-liquor-ratio operations as well as to meet the more restrictive environmental and energy needs of today's world. As early as the mid-1970's, it pioneered the application of conservation technologies to reduce waste discharged from the textile industry. In order to meet ever changing environmental needs, the company is continuously assessing these needs and is undertaking research to fully understand and fulfill them.

The company's environmental system group interacts with suppliers of filtration/separation technologies and has consequently been able to provide a diverse range of technological solutions for handling and treatment of waste materials, with specific focus on:

- Recovery of valuable chemicals from waste streams for reuse
- Concentration of process fluids by removing or reducing water content
- Eliminating spray chemical systems for topical applications
- Separating hazardous or undesirable chemicals from waste streams for separate treatment or disposal.

Gaston County has also able to offer practical solutions to waste effluent problems with:

- Pretreatment equipment;
- Tailored membrane systems;
- Post-separation treatment systems.

For finishing of textile fabrics, performance enhancement/finishing chemicals are traditionally applied by means of spray system. In this process application efficiency is low, control over the degree of add-on penetration is inadequate and air-borne spray contaminates the surrounding area and poses a health hazard to nearby workers. In close collaboration with the textile and chemical industry, Gaston County has developed the foam technique for application of chemicals instead of the spray system. The foam technique or chemical foam system (CFS) is expected to give better application efficiency, uniform applicability, and much better control over penetration. The CFS incorporates micro-processor control capability for adjusting the foamed chemical application rate to conform to changes in range speed during start-up and shut-down. It also has a closed-loop clean-up feature to reduce effluent problems during start-up, stand-by, and clean-up phases in which chemicals are by-passed from the applicator nozzle to a system that recaptures the chemicals for proper disposal.

Thus, CFS is a more environmentally friendly system since it minimizes the use of chemicals and consequently reduces effluent at the source. In it further quest to keep the chemical waste discharge to zero, the company's CFS system has been further developed and offers two possible approaches. One is to take the proper strength of generated foam when in "stand-by" or at initial "start-up" and pass it through a foam separator unit which removes the air from the foam and returns the chemical solution for regeneration. The second means to accomplish zero discharge is to capture all flush water from the system and collect it in a remote tank from where this diluted solution could be returned to the chemical compounder for evaluation and reuse, if possible, or proper disposal if reuse is not possible. The CFS technology thus makes an effort to reduce consumption of expensive chemical applicants as well as minimize chemical waste discharge.

Gaston County has been carrying on research and development in the use of membrane technology for treatment of textile industry waste and has developed its ultrafiltration for this purpose. Ultrafiltration is a pressure membrane separation process by which an effluent stream is separated into two components. The purpose of the process is to recover valuable chemicals for reuse, or to isolate (in concentration) undesirable chemicals for more economical disposal. The isolated component is called the "concentrate," which may be either valuable or undesirable. The second component is the "permeate," which can be almost pure water or water with a fraction of solid materials.

While Gaston County is able to offer waste treatment systems for the textile industry which cover every process and use different category of membranes (inorganic or polymeric) to cover a wide range of effluent streams containing sizes, oils, waxes, dyes, caustic, etc., the use of membranes may not be compatible with all kinds of liquids since membranes are sophisticated and delicate, and may be damaged by certain chemicals and materials. For effective

operations, the system requires optimum conditions including temperature, cross-flow velocity, a high level of automation, strict internal housekeeping, and effective prefiltration. The cost of membranes is very high, while their life is short. Consequently, the use of membrane technology for control and treatment of textile wastewater under Indian conditions needs further examination and development, with specific emphasis on making the use of membranes less costly and more operator friendly for Indian conditions. Possibilities of collaborative arrangements whereby critical components of membrane system could be imported from the U.S., while the rest of the equipment be manufactured in India may be worth exploring.

b. **Strandburg Engineering Laboratory Incorporated**, Greensboro, North Carolina manufacturers advanced process control equipment for textiles. The company's new and upgraded "series 1600" of controllers for textiles includes a variety of textile instruments and controls developed by the over 40 year old company. The major control equipment includes moisture control monitors, stretch monitors, shrinkage monitors, fabric density and fabric width monitors, compaction monitors, thread counters, wet pickup, temperature pressure and exhaust humidity monitors, seam detectors, size add-ons, size encapsulation, and yarn evenness sensors which do a specific monitoring and control job or link together to form a distributed control system of their own to automate an entire textile process.

This control equipment uses advanced and sophisticated sensors and the appropriateness of such sophisticated equipment under Indian conditions needs to be examined. After such control equipment is modified to suit indian conditions, there can be a good scope for setting up joint ventures for the manufacture of such sensors for use by the Indian textile industry.

c. **Tubular Textile Machinery**, more popularly known as Tube-tex, designs, develops, and manufactures a wide range of textile finishing machines. The company has originated many unique machines which have greatly improved the finishing technique around the world.

The Tube-tex HQII Processing Dryer is an integral part of the finishing process, featuring a unique combination of suction drum and/or conveyor drying to yield high production with minimum inherent length shrinkage. The company's Tubular Compactors and Open-Width Compactors are fully adjustable with control mechanisms to mechanically preshrink cotton and cotton blend tubular knit fabrics in the lengthwise direction.

The company's latest Four-Roll Pad is a module designed machine for spreading, extracting, and chemically processing circular knit fabrics in the tubular form. The machine performs the functions of detwisting, straightening of cross-line, stripe or pattern extracting excess moisture application of chemical finishes, and flat folding or feeding the fabric into entry spreader or drying range. For continuous application of dye stuff on tubular knit fabrics, the

company's DyRol is a specialized machine incorporating the latest technique for increased penetration of dye stuff, elimination of air from inside the tube, and providing a driving force for tensionless control of the fabric.

The company's computerized automation and control devices inlcude the width monitor, the yield monitor, and the stitch counter which can be used alone or together as monitoring devices or as monitoring control devices for making the process more efficient and productive. The computer automatically makes any required adjustments on a continual basis; it virtually eliminates the possibility of operator error with regard to fabric output.

d. **SheLyn Incorporated** is engaged in developing color control systems and in the development and application of color technology. It has developed an advanced PC based color formulation/quality control software system designed for both accuracy and flexibility. It combines the latest developments in color matching and color assessment, and the package may be configured with most commercially available spectrophotometer, thus protecting the users investment in software and data from obsolescence caused by changes in instrument technology. The equipment has an optional video display package to provide both automatic and interactive color displays. The package incorporates color and primary dye evaluation, a formulation and correction routine, video and graphic displays enabling color assessment, data storage for color samples (up to 10,000), and a color search function for quick color matching.

e. **The Hunter Associates Laboratory (Hunterlab)** develops and manufactures instruments to measure appearance and color characteristics. Its spectra photometers can be used for color matching, color adjustments, research, and quality assurance. The Hunterlab color matching software system has computerized the visual trial and error methods once used for color matching. This reduces the risk of human error by automating the selection of colorants and quantities needed to make a match. The system enables the user to read the target color, store it in the computer, and predict formulas that match this color, including weight and volume calculations. Hunterlab's Colorimeters are well suited for quality inspection applications where the primary goal is to ensure production of consistent color day after day. On-line colorimeters are spectrometers stream-line production, reduce down-time, and also reduce off-color waste material.

IV. CONCLUSIONS

Environmental protection and preservation has become a global concern as damage to the environment is being caused in many ways, including industrial pollution in general, and pollution by the textile industry in particular. The environmental protection laws are strict and exhaustive in the U.S., and their implementation is also quite effective. Protection of the environment from textile waste discharge is broadly considered at two stages. First, at the source of effluent generation by minimizing effluent through process modifications, in-plant modifications, use of eco-friendly chemicals and dyes, minimum and optimum use of polluting dyes and chemicals, and recycling and reuse of such dyes and chemicals which have been reclaimed from the textile waste. The second stage consists of proper treatment of textile wastewater before its discharge into a stream or municipal wastewater treatement system.

Research and development work with regard to minimization, reduction and treatment of textile waste is being carried out in the U.S. by various organizations/institutions both in state and private sector. The research and development in states is mainly directed towards the second stage, i.e., treatment of wastewater, both sewage and a combination of sewage and industrial wastewater. Research in the private sector has close links with the textiles and dyes and chemical industries. In the case of such research related to textile wastewater, textile industrial associations funded mainly by the industry, work closely with the industry and the member companies for applied research in both minimization and reduction of waste through process and equipment innovation, as well as in the treatment of textile wastewater. The applied research carried out in the textile universities has also contributed a lot towards working on solutions for this problem.

In the course of interaction with various institutions and organizations, the delegates found that the industry-funded research organizations showed a reluctance to share details about research in progress. Environment protection being a global issue affecting human kind in general, a more open approach encouraging sharing and interchange of information is desirable. While it is true that research and development in the U.S. in this field is quite advanced, it is also true that a lot of work has also been done in India on wastewater treatment and subsequent use of treated wastewater for growing plants. The EBE delegates dediced that a closer coordination and interaction between research being carried out in both the countries in the area would result in development of more effective methods of wastewater treatment and reuse of treated wastewater.

The visit to the wastewater treatment facilities, particularly from the textile industrial units, was very useful and informative. While the "activated sludge technology" is still common for treatment of municipal wastewater, the "extended aeration activated sludge" and "aeration lagoon" systems based on the aerobic treatment have been in use for treatment of textile waste for the past decade and a half, and have been found to be quite successful. This treatment system which is very easy to operate, cost effective, and flexible in nature would be appropriate for the treatment of textile

wastewater in India.

The present technologies for textile processing in the U.S. are very advanced and the machines currently in use are highly automated with a high degree of sophistication and built-in computer systems for control monitoring, and corrective action. The environment prevailing in India is different from that in the U.S. both from the point of view of availability of a highly skilled and technical work force, as well as adverse and extreme weather conditions which require modifications in these machines so as to make them appropriate for Indian conditions. There is a great scope for joint/collaborative ventures for the manufacture and use of modern textile processing machines after appropriate modifications to suit Indian conditions. This kind of exchange would be mutually beneficial to the textile manufacturing industry in the U.S., as well as the textile industry in India.

V. RECOMMENDATIONS

1. It was found that a basic knowledge of end-of-pipe waste treatment systems would greatly benefit participants *before* they embark on a study tour of this nature. It is recommended that a short course using the EPA publications *Environmental Pollution Control-Textile Processing Industry (EPA 625/7-78-002, October, 1978)* and *In-Plant Control of Pollution (EPA 625/3-74-004)* be given to future exchange participants before their visit to the U.S. on a textile technology assessment tour.

2. Exchange of information is critical to the successful implementation of waste reduction measures in the Indian textile industry. The Office of Waster Reduction, Department of Environment, in North Carolina has been extremely productive in gaining knowledge regarding waste minimization in the textile industry. An information clearinghouse had prepared many databases which could be of great help to industry. A plan for collateral information exchange between the Waste Minimization Group in Surat and the Office of Waste Reduction should be implemented. This information exchange would focus on the latest developments on the environmental field, especially pertaining to the textile industry.

3. Groups from Rajasthan as well as from Gujarat should become members of the American Association of Textile Chemists and Colorists (AATCC) to gain information from the services extended by the Association in various aspects of color and wet processing of textiles.

4. In 1992, Appropriate Technology International (ATI) of Washington, D.C., had entered into a Memorandum of Understanding (MOU) with SIDBI. ATI recommended setting up a common effluent treatment plant (CETP) in major textile processing centers based on the "aerated lagoon system" technology. After viewing this technology first-hand, the textile industry delegates realized that this treatment system was easy to operate, cost-effective, and flexible in nature and is appropriate for the treatment of textile wastewater in India. It is therefore, recommended that the "aerated lagoon" system be used as the technology of choice insetting up the CETP in the major textile processing centers in Rajasthan.

APPENDIX A

PHOTOGRAPHS

CHARLES STRANDBERG, STRANDBERG INSTRUMENTS

ROLAND CONNALLY, SHELYN, INC.

Jim Rodgers, TUBETEX

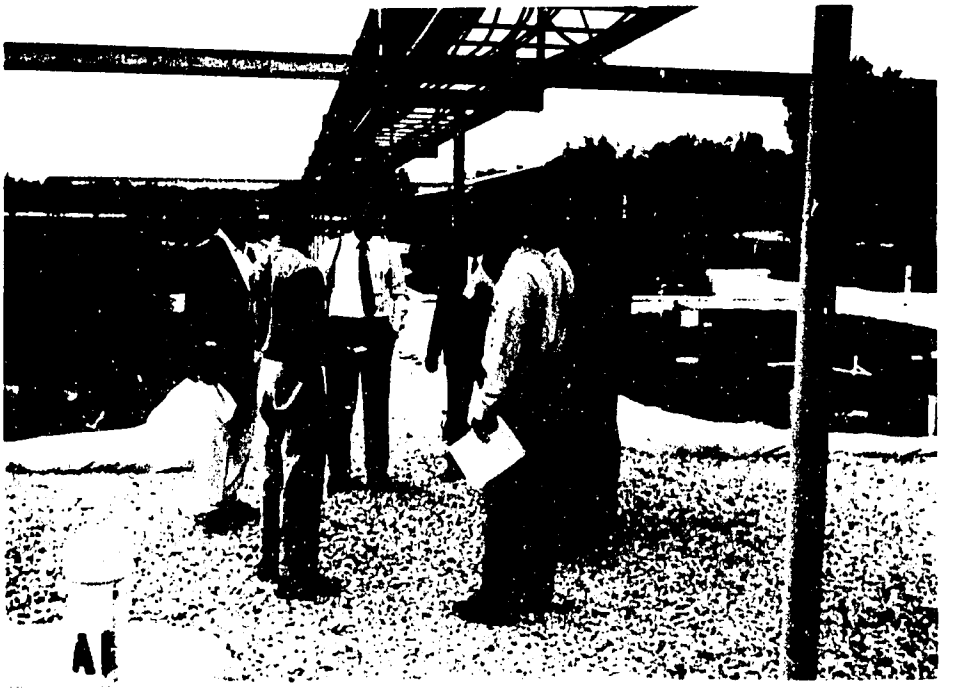
STEVE LARRIER, J. P. TEXTILES.

CHRISTOPHER AURICHS, GASTON COUNTY WITH FOULED MEMBRANE

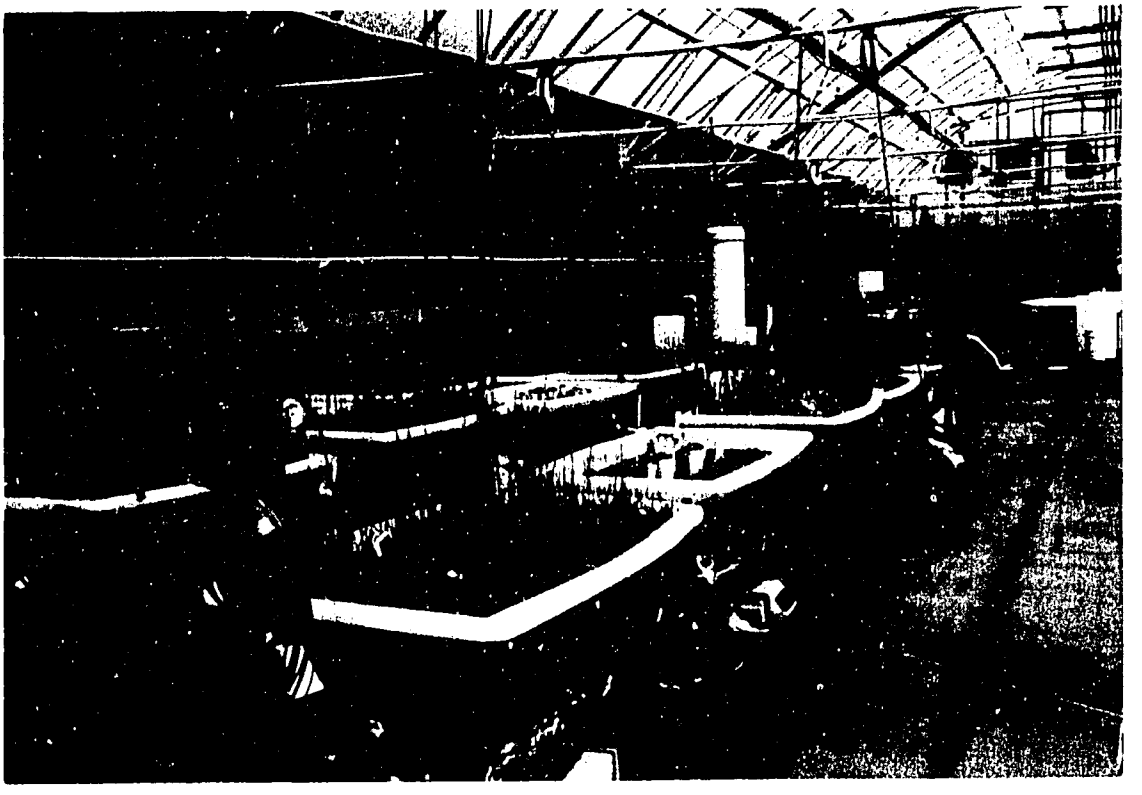
DON SPURRIER, GASTON COUNTY AT J. P. TEXTILES

RAY FUENTES, PLANT OPERATOR, SUGAR CREEK PLANT

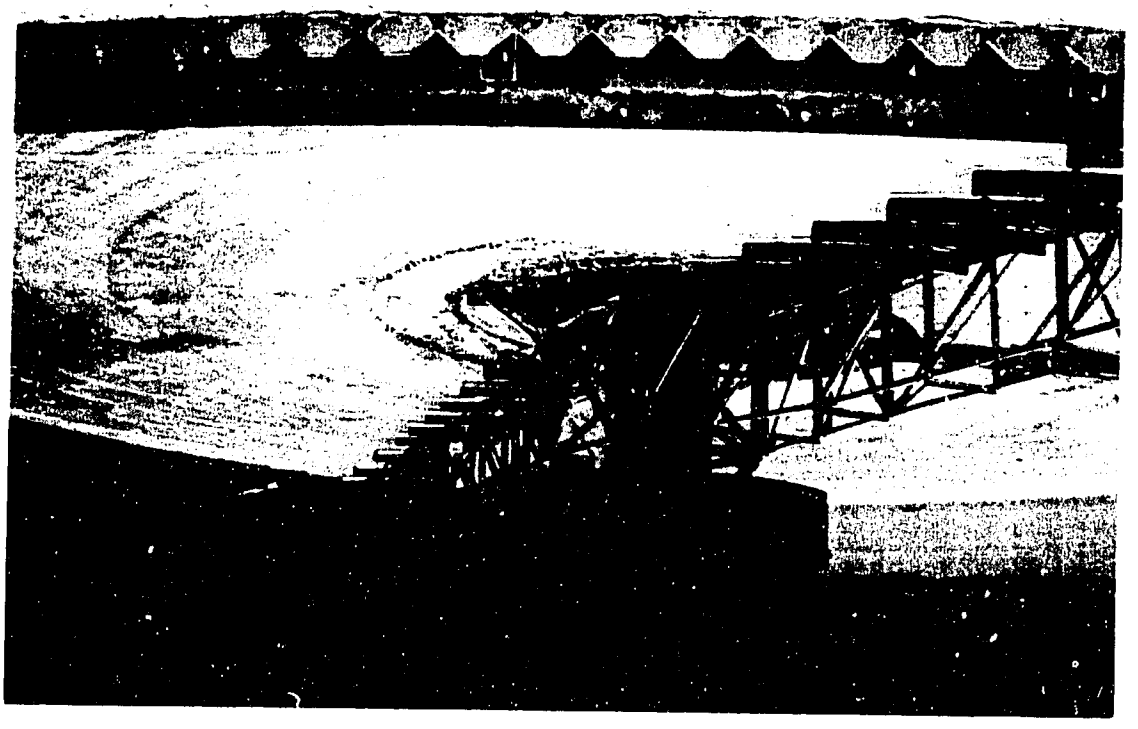
CHRISTOPHER AURICHS, GASTON COUNTY



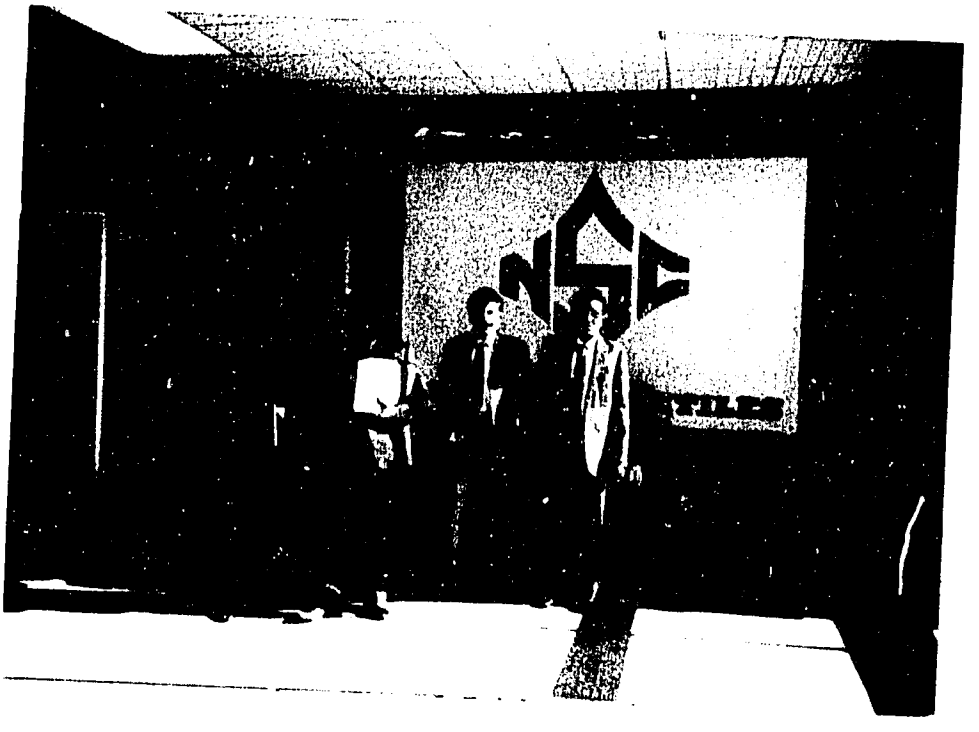
Tennessee Valley Authority, Wetland), Muscle Shoals, Alabama
(TVA)



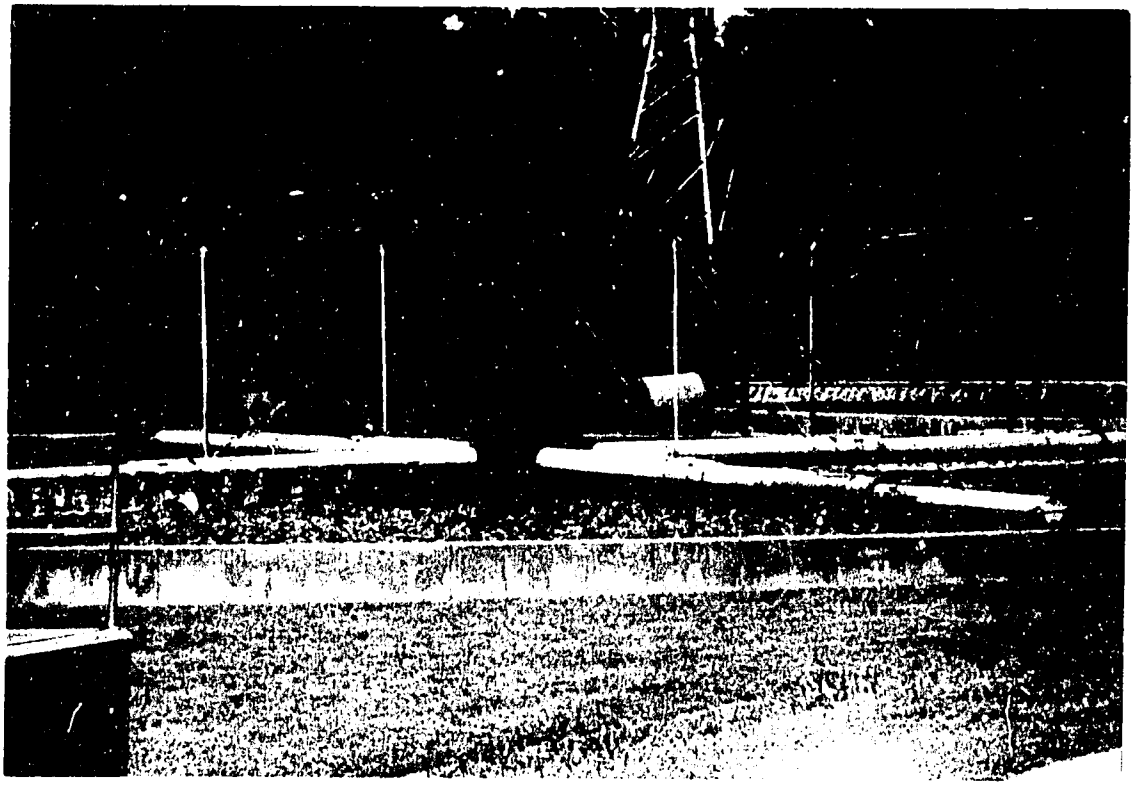
TVA, Muscle Shoals, Alabama



Sugar Creek Sewage Treatment Plant,
Charlotte, NC



North Carolina University, Dept of Textiles
Raleigh, NC



Sugar Creek Sewage Treatment Plant, Charlotte, NC.

North Carolina State University, Raleigh, NC

American Association of Textile Chemists and Colorists, Research Triangle Park, NC

J.P. Textiles, Forest City, North Carolina

APPENDIX B

ITINERARY

ITINERARY

April 27	Sugar Creek Plant of Charlotte, NC - Wastewater Treatment System
April 28	Gaston Country Dyeing Machine Co., Stanley, NC, and J.P. Textiles Co., Forrest City, NC
April 29	Tubular Textiles Co., Lexington, NC, and Hanes Knitting, Division of Sara Lee Corporation, Winston-Salem, NC
April 30	High Point, NC
May 1	High Point, NC
May 2	Strandberg Instrument Laboratories, Inc., Greensboro, NC and Shelyn, Inc. - HunterLab, Greensboro, NC
May 3	Textile School, North Carolina State University, Raleigh, NC and Burlington Knitted Division of Burlington, Industries, Raleigh, NC
May 4	American Association of Textile Chemists and Colorists, Research Triangle Park, NC
May 5	Office of Waste Reduction, North Carolina Department of Environment
May 6	Institute of Textile Technology, Charlottesville, VA

APPENDIX C

PERSONS AND ORGANIZATIONS VISITED

PERSONS AND ORGANIZATIONS VISITED

DATE	ORGANIZATION	PERSONS MET	DESIGNATION	LOCATION
4/25/94	WRATT (Waste Reduction & Tech. Transfer)	Roy O. Nicholson Edwin D. Myers Peter A. Goudreau	CEO Ch. Tech. Off. Waste Mgmt. Consultant	Muscle Shoals, AL 35660-1010
4/25/94	TVA-Constructed Wetlands	Peter Burgoon	Research Eng'g. Biotechnology	Muscle Shoals, AL 35660-1010
4/25/94	Tee Jay's Inc.			
4/26/94	Alabama Dept. of Environment	Wm. Gerald Hardy Daniel Cooper Philip Davis	Chief, Eng'g. Chief, Sp. Proj. Chief, Industrial Water Division	Montgomery, AL 36130
4/26/94	West Point Stevens, Opelika Finishing Plant	Eddie Lanier David Chunn	Mgr. Env. Eng'g. Jr. Mgr. Env. Eng'g.	Opelika, AL 36801
4/27/94	Charlotte City/ Sugar Creek Effluent Trt. Plant	Roy Fueules	Plant Operator	Sugar Creek WWTP Charlotte, NC

4/28/94	Gaston County Dying Machine Company	Chris Aurich H.B.G. Goettsch Don Spurrier	V. President Product Manager Dir., Int. Sales	Stanley, NC 28164
4/29/94	J.P. Textiles	Kumar Bavishi	President	Forest City, NC
4/29/94	Tubular Textile Machinery	James Rodger	Int'l. Sales Engineer	Lexington, NC 27293
5/2/94	Strandberg Eng'g. Laboratories	Chrls. Strandberg John Strandberg Bob Strandberg	President Prodn. In Charge R&D Chief	Greensboro, NC 27405
5/2/94	Shelyn Inc.	Roland Connelly Ann Campbell Malcolm Lloyd	Sr. President Mgr. Applications Dir., Hunter Lab.	Greensboro, NC 27408
5/3/94	Coll. of Textiles, NCSU	Dr. Brent Smith Leon Moser Dr. Sam Hudson	Professor Extn. Specialist Assoc. Professor	NCSU, Raleigh, NC 27695
5/3/94	Burlington Knitted Fabrics, Wake Plant	Sandy Richards N.D. Patel Tim Holland Mr. Scott Mr. Herbs	CEO Lab Manager Eng'g. Dept. Mgr. Dying Manager Finishing Mgr.	Wake Forest, NC 27587
5/4/94	AATCC	William Martin Jerry Tew	Exec. Director Tech. Director	Research Triangle Pk, NC

5/5/94	Office of Waste Redctn., NCDEM	Gary Hunt David Williams	Director Engineer	Research Triangle Pk., NC
5/6/94	Institute of Textile Technology	Dan McCreight Jack Middleton Mike Bahorsky	V.P., Operations Asst. Dev.& Adm. Environ.l Spec.	Charlottesville, VA 22902

APPENDIX D

BUSINESS CARDS OF PERSONS VISITED

DON W. SPURRIER
Director of International Sales
704-822-5150

GASTON COUNTY
DYEING MACHINE COMPANY
P. O. Box 308
Stanley, NC 28164 USA
Main Office: 704-822-5000
Fax: 704-822-0753
Telex: 154905 GASDY MTHY

H. B. G. (Guy) GOETTSCH
Product Manager
704-263-6037

GASTON COUNTY
ENVIRONMENTAL SYSTEMS
P. O. Box 308
Stanley, NC 28164 USA
Telephone: 704-263-6000
Fax: 704-263-0954
Telex: 154905 GASDY MTHY

GASTON COUNTY *Dyeing Machine Co.*
ESTABLISHED 1971

CHRISTOPH W. AURICH
VICE PRESIDENT

P.O. Box 308
STANLEY, N.C. 28164
704-263-6023

J.P. TEXTILES
Associates, L.P.

307 Vance Street • P.O. Box 1017
Forest City, North Carolina 28043

Kumar Bavishi
President

Phone (704) 245-8080 Fax (704) 245-0265

Tubular Textile Machinery
A Carlisbrook Company

James A. Wellmaker
Sales Director
National Accounts

tube-tex.
Hargrave Road at I-85
P.O. Box 2097
Lexington, NC 27293-2097
704-956-6444
Telex: 575079
Fax: 704-956-1795

Tubular Textile Machinery
A Carlisbrook Company

James B. Rodgers
International Sales Engineer

tube-tex.
Hargrave Road at I-85
P.O. Box 2097
Lexington, NC 27293-2097
USA
704-956-6444
Fax: 704-956-1795

SARA LEE KNIT PRODUCTS

Jim Davis
Plant Manager

700 South Stratford Road
Winston-Salem, NC 27103
919 519-5917
Fax: 919 519-5981

Hanes Underwear Hanes Printables Stedman Pannill

STRANDBERG

CHARLES F. STRANDBERG
PRESIDENT

STRANDBERG ENGINEERING LABORATORIES, INC.
1302 N. O'HENRY BLVD. (U.S. 29 N.) • GREENSBORO, NC 27405 • U.S.A.
(919)274-3775 • TELEX: 574363 • FAX: (919)272-4521 • CABLE: STRANDBERG

Ann Campbell Laidlaw — Manager, Color Applications

SheLyn Incorporated
Color Technology Applications & Development

1108 Grecade Street
Greensboro, NC 27408

Phone (910) 274-1963
FAX (910) 274-1971

Roland L. Connelly, Sr. — President

SheLyn Incorporated
Color Technology Applications & Development
1108 Grecade Street
Greensboro, NC 27408

Phone (910) 274-1963 FAX (910) 274-1971

Malcolm B. Lloyd
Far East Director

HunterLab
Hunter Associates Laboratory, Inc.
11491 Sunset Hills Road
Reston, VA 22090
Telephone: (703) 471-6870
FAX: (703) 471-4237
Telex: 292821 HLAB UR

World Environment Center 419 Park Avenue South Suite 1800 New York, NY 10016 USA
Tel: (212) 683-4700 FAX: (212) 683-5053

WEC/US-AEP

Environmental Business Exchange (EBE) Trip Reports

Febuary 22, 1995

Trip Reports as per Cooperative Agreement (CA) AEP-0015-A-00-2055-00 in Support of the U.S.-Asia Environmental Partnership

EBE ID#	EBE DATES	TITLE OF TRIP REPORT
INDI-1I	11/7-23/93	Oil Absorbent Demonstration
INDI-1K	12/6-29/93	Review of Incinerator Operations, Indian Thermal and Cyno Clean
INDI-2	4/23 - 5/6/94	Review of Pollution Prevention Control Technology in the Textile Industry
INDI-5	4/30 - 5/10/94	Clean Coal Technology Evaluation
INDI-1P (1&2)	5/94-8/94	Clean Technology for Paper Mills - Esvin - Parts 1&2
INDI-1R	6/18-30/94	Evaluation of Biological Formulations for Industrial Wastestreams Treatment (Premier Ziba)
INDI-1Q	6/18-7/1/94	Indian Boilers Manufacturers' Association Trade Mission
PHIL-8	9/27-10/6/94	Technical Assistance on H2S Gas Abatement Systems (PNOC)
HONG-1	10/23-11/9/94	Coleman Energy and Environmental Systems Technology Transfer
KORE-1	12/9-22/93	Fuel Gas Desulfurization Technology Assessment (KEPCO)
INDI-1L	1/17-2/23/94	Corporate Environmental Mission (IT Corporation Exchange)
INDI-4	3/11-30/94	Evaluation of CS_2 Recovery in Rayon Mills