MEMBRANE TECHNOLOGY IN TEXTILE OPERATIONS

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INTRODUCTION

The textile industry is characterized by using a large quantity of chemicals and huge quantities of water. Detergents and caustic are used to remove dirt, grit, oils and waxes. Bleach is used to improve whiteness and brightness. Dyes, fixing agents and many inorganics are used to provide the brilliant array of colors the market demands. Size is added to improve weaving. Oils are added to improve spinning and knitting. Latex and glues are used as binders. A wide variety of specialty chemicals are used such as softeners, stain release agents and wetting agents. In some ways, the needs of the textile industry was the engine which drove the development of the chemical industry.

Many of these chemicals become part of the product Many of the chemicals perform a necessary function, but are removed from the fabric. State authorities and local municipalities have begun to target the textile industry to clean up the wastewater that is being discharged from the textile mills. Regulators are looking closely at toxicity due to high salt, the ever present BOD, non-destructible COD, heavy metals, and color of the effluent As the mill comes up for a new discharge permit, many are finding that the effluent being discharged threatens permit renewal.

Membrane separations are evolving as a solution to the many problems a mill may be experiencing. Membranes can provide a solution in such areas as: color removal, BOD reduction, salt reduction and reuse, PVA recovery, and latex recovery. Membrane technology is unique in that it can provide a return on investment as a solution to pollution abatement. Membrane solutions are generally in keeping with the Clinton/Gore philosophy of pollution prevention is better than pollution treatment. Capital investment is competitive with conventional end of pipe treatment because membranes have become more of a commodity, and because a point source strategy can be employed. In many cases, valuable products can be reclaimed and reused, adding to an overall cost reduction.

MEMBRANE BASICS

There are two keys to membrane filtration which differentiate membrane application from conventional filtration. First, the membranes are asymmetric with the small side of the pore facing the feed. This feature minimizes the pressure drop across the membrane, and eliminates any tendency to plug the membrane. Second, all membrane systems operate with a strong cross flow over the surface of the membrane (Figure 1). Cross flow limits the build up of a filter cake (or concentration polarization layer in membrane lingo) to a few microns.

Solutes, whose sizes are greater than the pore size of the membrane, are retained and concentrated forming a liquid stream called the concentrate or retentate. Water and solutes smaller than the pores pass through the membrane and are called the permeate. Membrane operation is characterized by the flux, or flow rate per unit area of membrane, and by its retention or the percent of each solute species which does not pass through the membrane.

In purchasing a membrane system there are three major considerations. What type of membrane best suits my needs? What configuration of the membrane and operating conditions will best balance capital costs, operating costs and ease of operation? How are the membrane systems integrated into my plant? This section will give some guidance in making these choices.

The four common membrane types are: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). These processes differ in the pore size (Figure 2).

Microfiltration is used to separate colloids from polymers with pores of 0.1 to 1 micron. MF will typically show 90+% reduction in turbidity or silt density index. Typical application areclarification of juices and clarification of sugar solutions. Microfiltration-membrane? are made of several polymers including Poly(ether suifone), poly(vinylidiene fluoride) and poly(sulfone). Ceramic, carbon and sintered metal membranes have found market niches where extraordinary chemical resistance or where high temperature operation is necessary.

Ultrafiltration is used to separate polymers from salts and low molecular weight materials, with pores of 0.001 to 0.1 micron. Turbidity is sharply reduced by 99+%. Polymers are retained for reduced TOC, BOD and COD. A wide range of molecular weight cutoffs are available from 1000 to 500,000 daltons. Typical applications are haze stability in juices, concentration of E coat paint, whey protein concentration and concentrating stable oily water emulsions. UF is an excellent means to remove metal hydroxides, reducing the heavy metal content to 1 ppm or less. Additional water can be added to wash salts and monomer out in a process known as diafiltration. UF membranes are mostly polymeric of the same materials as MF, but there are also dynamically formed metal oxide membranes.

Nanofiltration is used to separate sugars and divalent salts from water and monovalent salts. NF has found wide application for water softening. It also is demonstrating an ability to decolorize solutions. NF modules are extremely sensitive to fouling by colloidal material and polymers. For this reason extensive pretreatment is required. UF makes an excellent pretreatment substitute by eliminating the polymer addition, chlorine disinfectant, DAF or mixed media prefiltration. Virtuallly all NF and RO membrane are thin film composite membranes.

RO is used to remove almost everything from the water. NaCl and simple sugars show 98% or better retention by the membrane. Like NF, RO is very sensitive to fouling and must be carefully pretreated.

The **operating conditions** which influence productivity and rejection are transmembrane pressure, solute concentration and recirculation flow rate. The strong cross flow which limits the buildup of a filter cake results in expected operational characteristics. First the flux in membrane separations does not decrease with time as in cake filtration. In most applications increasing the transmembrane pressure does not necessarily increase flux. This is because the filter cake responds to the increased convection of solute to the membrane surface by increasing the thickness of the cake. The cake thickness is primarily controlled by the velocity of the cross flow. Increasing velocity generally increases the flux by increasing the rate at which the filter cake is swept away and reducing the cake resistance. Increasing concentration typically decreases flux because of the increase in convection to the membrane surface. Typical responses to changes in cross flow rate, transmembrane pressure and concentration are shown in Figure 3.

As a rule of thumb, the smaller the pore size the higher the operating pressure, the capital investment and the operating cost. MF and UF operate at 20 to 100 psi transmembrane pressures (P_{tm}) and velocities over the membrane surface of 1 to 10 meters/set. Typical fluxes for UF and MF are 20 to 400 gallons/sq ft/day (GFD). Nanofilters operate at 300 to 600 psi P_{tm}, with velocities of 20 to 100 cm/set. Typical NF flux rates are 5 to 30 GFD. The P_{tm} in RO is typically 500 to 1000 psi, with cross flows of 20 to 100 cm/set. The range of typical RO fluxes are 5 to 15 GFD.

Fouling of the membrane surface is the bane of membrane operations. There are two types, colloidal flocculation or inorganic scaling above the membrane surface and adsorption of organics to the membrane. Extensive literature exists on this problem, but relatively few cures. Fouling layers are removed by appropriate cleaning procedures. The most common procedures are caustic detergent for removal of dirt, oils and colloidal material, acids for metal hydroxides, and oxidizing agents for adsorbed organics.

Membranes are packaged in several **configurations,** the most common are spiral wound, hollow fiber and tubular as shown in Figure 4. Flat plate configurations similar to plate and frame filter presses are used to a limited extent Spiral configurations are generally the least expensive to buy and operate because of the high packing density and the turbulence promotion generated by the feed spacer. Unfortunately, spiral modules are susceptible to plugging of the module with colloidal or fibrous material. Next most economical are the hollow fiber systems. Unfortunately, these modules are limited to relatively low pressures with resulting lower fluxes. Tubular modules are extremely durable and have long life and high fluxes, but generally are more expensive to purchase and operate. RO is available principally as a spiral, but l/2" tubular modules and hollow fiber are available. NF is available only in spirals, UF and MF are available in all configurations.

Membrane stages are **integrated into the plant** as either modified batch or continuous stages in series operations (Figures 5 and 6) Modified batch systems utilize a continuous feed, produce a continuous permeate of clean water, but the concentrate is produced batchwise. Feed and bleed continuous operations take a constant feed rate, and produce permeate and concentrate at constant rates. Modified batch operations are generally less expensive because of higher average fluxes and less hardware.

Your membrane system supplier can best advise you on implementing membrane solutions to your problems.

APPLICATIONS IN THE TEXILE INDUSTRY

With environmental regulations tighten, UF offers several varied applications covering many aspects of textile processing. These application&e unique because they provide a return on investment while abating a water pollution problem. A typical income statement for evaluating the membrane application is provided in Table I. The following paragraphs present descriptions of some the uses membranes have in textile operations and their benefits. In ail cases the membrane process is used as a point source treatment minimizing capital and operating costs.

PRINTING The printing operation uses large quantities of water for washing the continuous rubber belt The wastewater is laden with fine pigments and polymeric binders giving the stream high color and BOD. UF membranes remove the color and the binder. The clean permeate has a 90% reduction in BOD and 100% reduction in color. The water can be recycled back to the print machine for reuse (Figure 7.)

The best membrane for this application is the one inch FEG tube used in a modified batch mode. It readily handles the high viscosity at the end of the run. It can be mechanically cleaned with a sponge ball or pig and it has a long membrane life.

Economics are based on the reuse of the water and reduction of BOD. Lower water costs are realized through reduced volumes to be purchased and treated and the lower BOD level can reduce fines and surcharges. A two year payback can be realized if the water and sewer costs are $7.50/1000 gal.

SCOURING OPERATIONS Scouring operations generate large BOD, oil and grease loadings on the sewer system. Heavy metals in cotton greige goods sometimes cause a problem also. Typically, these emulsions are stable and hard to treat by traditional means. UF retains and concentrates the emulsion to 30-50% oil which can be economically hauled away. At these concentrations the O/W emulsion supports combustion and can be used as fuel. Heavy metals are reduced to their solubility limit, usually less than 1 ppm.

Scouring operations are best with ceramic or hollow fiber membranes. The best operation for continuous ranges is as a kidney shown in Figure 8. The kidney setup continually removes oils, greases and dirt, concentrating them in the membrane systems process tank, and recycles the surfactant laden permeate back to the scouring bath. The best process mode for batch scouring operations is modified batch (Figure 9.)

The driving force in this application is pollution control. Water reuse of the permeate is possible, along with the heat savings. Water reuse gives a two year payback if the water price is $5.50/1000 gal

DYESTUFFS/DYEBATHS Most dye baths have three major pollutants: the dye which presents an aesthetics problem in waters used for recreation, heavy metals incorporated in the dye, and the salt which can present a toxicity problem when discharged to small streams. UF is capable of completely separating many dyes such as: vat, acid, premetallized, dispersed and direct dyes from the brine. Some dye manufacturers use UF to wash excess salt out of the dyes. NF can be used to separate fiber reactive dyes and cationic dyes from the salt. The salt is recovered for reuse, and the dye can be discarded. A system may look like Figure 9.

Cost savings are generated from the reuse of the salt, reuse of the water (less water purchased, lower sewer charges), recovery of heat from the water and the value of the dyes if the dye is reused. Salt recovery from the dyebath alone has 50% return on investment while reducing 99% salt toxicity by about 75%. A system to remove color and recover salt from fiber reactive dyeing has a two year payback if the water price including purchase, sewer charges and fines is $4.50/1000 gal.

LATEX RECOVERY Latex is an expensive material used as the binder in carpet manufacturing. In general, latex is mixed with an extender such as calcium carbonate. The waste stream is too dilute to reuse and is discarded causing a aesthetics and BOD/COD problem. Latex recovery by UF is a standard operation for the many latex manufacturers and users.

Latex recovery produces several principal benefits. Two benefits are: decreased purchase of latex and BOD reduction. The permeate is laden with surfactant, making excellent process or cleaning water. A two year payback from latex recovery is possible from a 0.5% latex waste stream.

SIZE RECOVERY PVA size recovery has long been used in large, integrated weaving plants to recover and concentrate the size from the desizing bath (Figure 10.)

Size recovery can be use economically on small streams to remove the size from desizing baths. The size can be reused in-house or sold to a nearby weaving company. As a last resort, the size can be hauled off as waste. The hot permeate can be recycled back to the desizing bath. Poly(acrylic acid) and polyester sizes can be recovered this way also.

Cost savings are generated from lower PVA purchases, lower BOD surcharges, heat recovery, and water reuse. In most cases, the recovered size may be reusable. If the size is sold to a weaving company, this eliminates hauling costs and improves the return on investment For an integrated weaving company practicing size recovery, the payback is several months.

INDIGO DYE RECOVERY Indigo dye is only 80% fixed onto the fabric with the remainder being washed away. In the quinone form it is highly insoluble in water and can be readily concentrated by UF. The concentrate can be blended with fresh Indigo, reduced with hydrosulfite and caustic and reused.

The best configuration for this application is the 1” tube. It has exceptionally long life of several years. The high cross flow velocity gives high stable fluxes keeping system and operating cost low. The typical payback on a continuous rope dyeing operation is about one year or less.

WATER SOFTENING Nanofiltration is an excellent alternative to ion exchange or green sand water softening. Many communities use NF to soften, decolorize and eliminate bacteria and viruses from the drinking water supply.

The principal advantages are low maintenance, no regeneration costs, low discharge volume.

FEED WATER PRETREATMENT Water quality is paramount in high quality dyeing operations. Hollow fiber UF removes color bodies which interact with the dye and compete for sites on the cloth. It also removes the colloidal material which causes spotting. In this way a higher consistency dyehouse operation can be maintained.

CONCLUSIONS

Membrane processes have many cost effective applications in the textile industry. The cost competitiveness results from:

The ability to recover materials with value,

recycle water reducing fresh water consumption and wastewater treatment costs,

the use of a point source approach for minimum capital costs,

small disposal volumes which minimizes waste disposal costs,

reduction of regulatory pressures and fines

improved heat recovery systems.

The textile industry is advancing toward more a closed operation. Strategically placed membrane systems will play an important role in recovering chemicals which used to go to the sewer, and in providing the high quality water needed to produce top quality goods the first time, every time.

TABLE I

INCOME STATEMENT FOR EVALUATING MEMBRANE TREATMENT

INCOME SOURCES

Chemical Recovery (size, salt, detergents, caustic, latex, dyes)

Less Water Purchased

Reduced Sewer Charges

Reduced Sewer Surcharges (high volume flow, high BOD load, High COD/BOD ratio)

Heat Recovery

Eliminate Fines

Reduced Pollution Paper Work

OPERATING COSTS

Electricity (Recirculation pumps, RO/NF feed pump)

Membrane Replacement

Labor (10 hr/week)

Maintenance

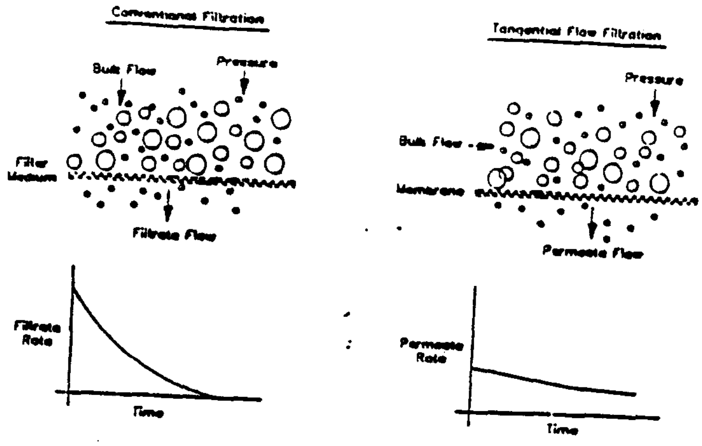

Fig. 1: Comparison of Flow Patterns

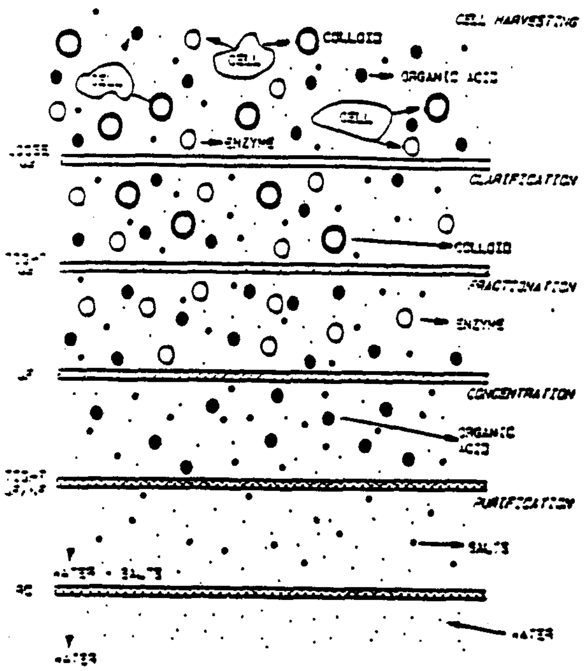

Fig. 2: Membrane Filtration Concepts

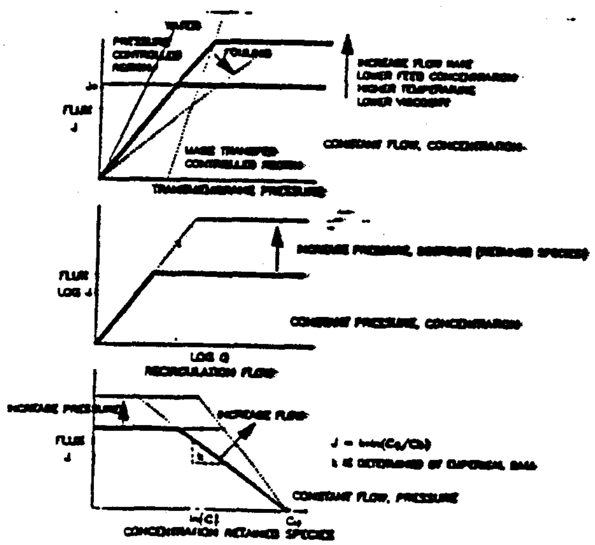

Fig. 3: Cross Flow Membrane Filtration

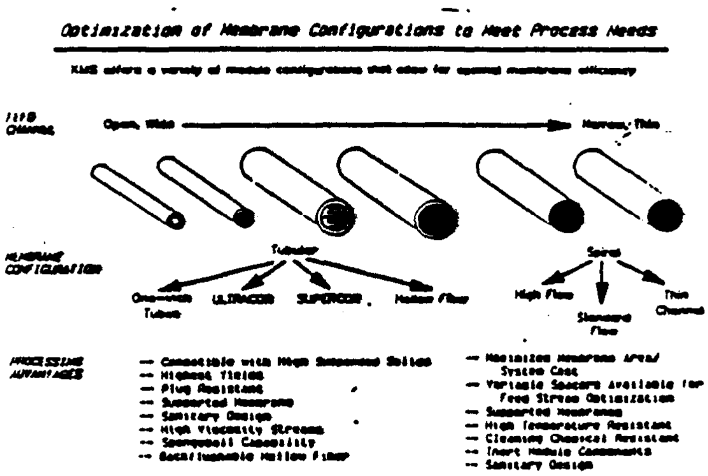

Fig. 4: Cross Flow Membrane Filtration

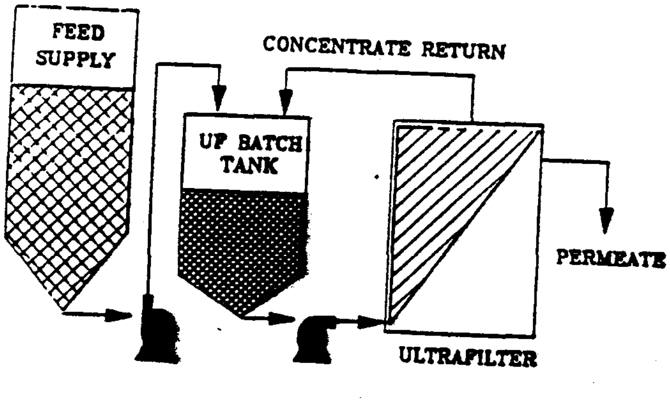

Fig. 5: Modified Batch

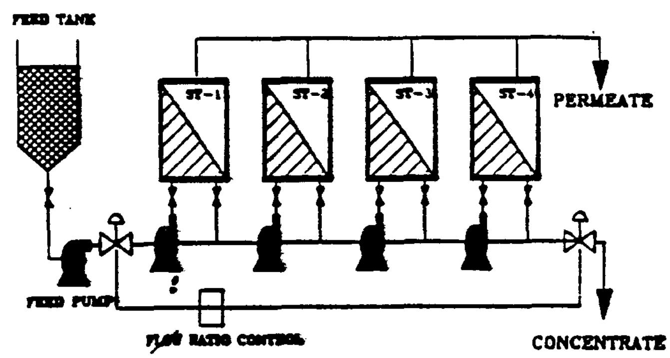

Fig. 6: Stages-in-Series

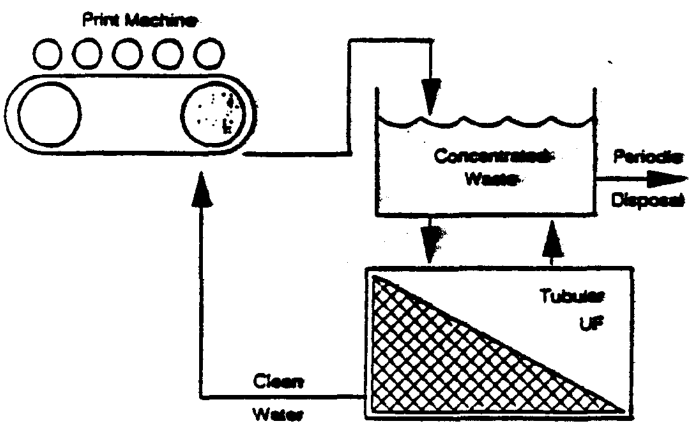

Fig. 7: Printing

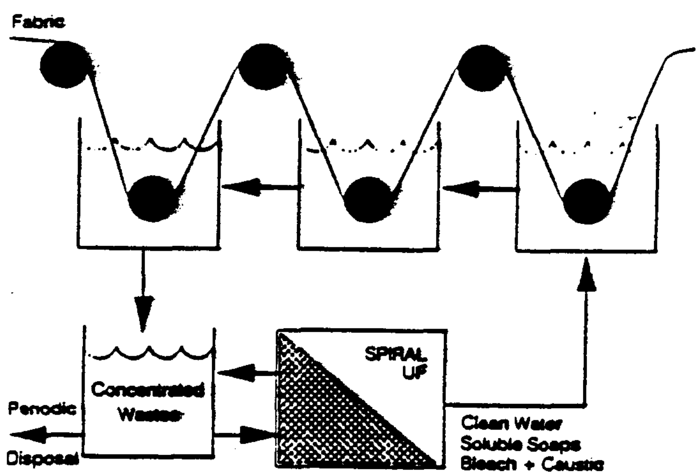

Fig. 8: Bleaching and Scouring

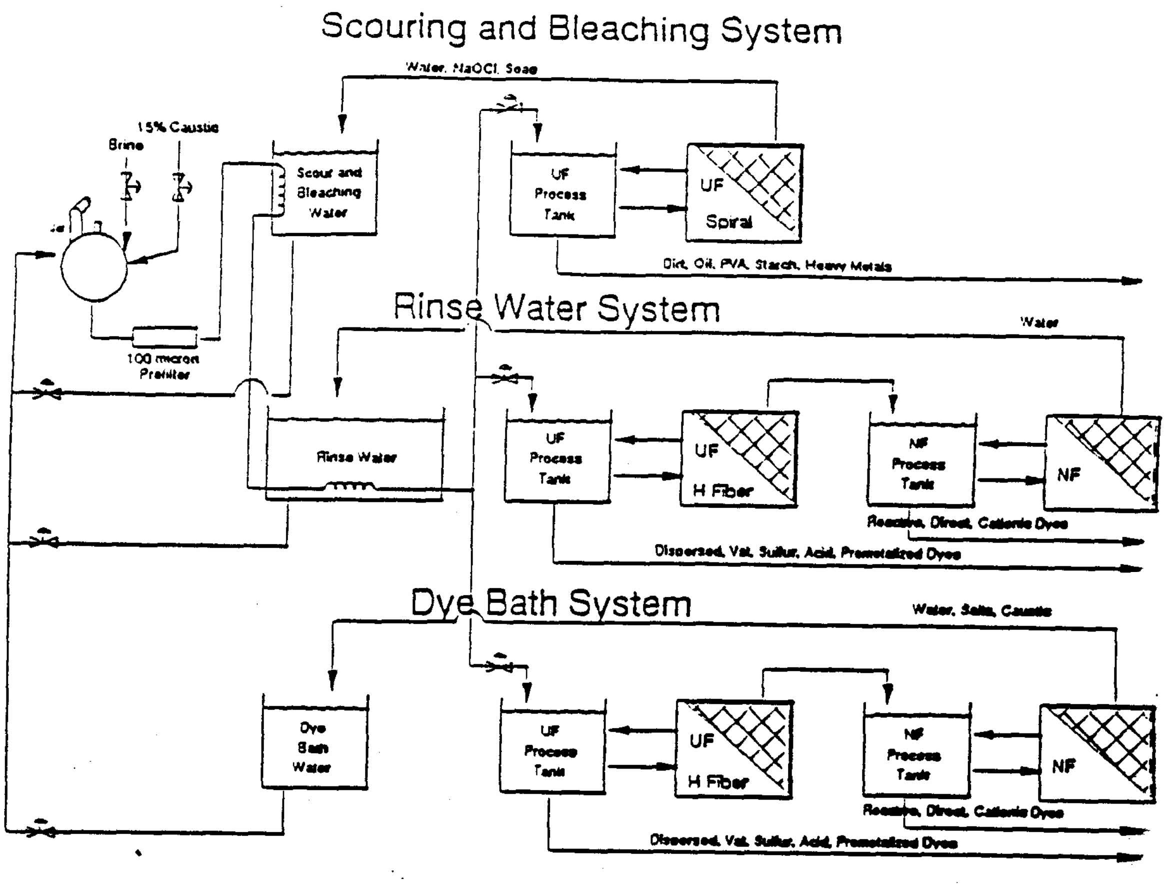

Fig. 9: Full Recycle of Jet Dyeing Machine Waters

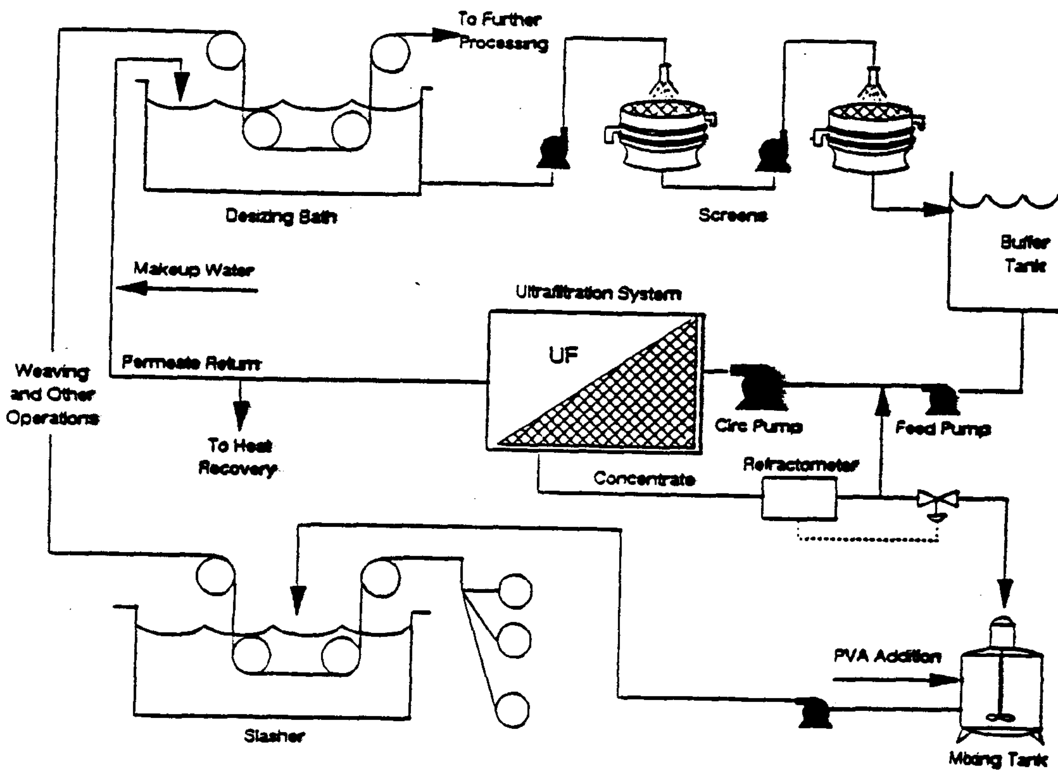

Fig. 10: Overall PVA Recovery System