Protecting the environment through waste water recycling and heat recovery in textile finishing

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It is difficult for textile finishing to escape the image of being an industry which causes emissions. However, there are ways to drastically reduce the difficulties associated with wet chemical processes. The report describes the increasing global problems in the area of water and energy policies, and presents a case study which demonstrates how it can be possible to run waste water free textile finishing operations.

Within the textile industry, textile finishing is one of the main sources of emissions. As a supplier of modern high-performance textile finishing machines which are both energy and water efficient, Benninger has now gone one step further and now also offers a new range of machines which are specifically designed to save even more water and energy. The key to this range are the diaphragm filtration systems which allow water, valuable materials and waste energy to be recovered (Figure 1: Zero Discharge).

Global water and energy shortages

In future, water is set to become an increasingly scarce and therefore extremely valuable resource. Demand for water is growing at more than twice the rate at which the world's population is growing. During the last 100 years, the world's population has increased threefold, while water consumption has risen by a factor of seven in the same period. Since 1970, the available amount of water per capita has been reduced by 40% as a result.

It takes around 2,500 – 3,000 litres of water to manufacture a single cotton shirt. The bulk of this is required to grow the cotton, but this is followed in second place by the wet finishing process. The first consequences of water shortages and waste water problems are already starting to be felt in the textile finishing industry. For example, new companies in China and India have not been granted approval to set up operations if they have not been able to present a convincing case to the authorities in terms of their approach to solving the issues of water consumption and waste water. In Europe, companies face closure for the same reason. Textile centres in Asia are reporting rapidly dwindling groundwater reservoirs and heavily salinated groundwater. As a result, many companies face challenges which threaten their very existence.

Holistic solutions

The global textile industry faces a new challenge. As a consequence of global energy and water shortages, the industry now needs environmentally friendly production methods. As far back as the mid-1990s, Benninger already moved away from the conventional role of a machine builder, and the company has since established itself as a supplier of equipment for wet finishing processes for woven fabrics and knitwear. Now the company is for the first time offering holistic solutions for the textile finishing industry under the banner of "resource management". These solutions stand for sustainable textile production which is both ecologically sound and ethical. Part of this approach involves adopting a more careful attitude to the use of water, energy and chemicals.

In addition to the textile finishing machines for woven fabric and knitwear, Benninger also supplies the matching diaphragm filtration systems, which can be equipped with a number of functions which enable the following processes:

a.) Separation of water from the contaminants introduced by the process, with subsequent recycling. The contaminants are concentrated to the point where no liquid waste is generated
(ZERO DISCHARGE). At least 80 % of the waste water is reused as process water.
b.) Recovery of recyclable materials from the waste water and reuse of these materials in the process (e.g. size, caustic soda etc.)
c.) Recovery of thermal energy

Figure 2 shows an ultrafiltration plant in the textile industry.

Diaphragm filtration system

In essence, the multi-stage diaphragm system comprises an ultrafiltration stage (Figure 1) and a downstream reverse osmosis stage. The ultrafiltration stage is equipped with a special ceramic diaphragm. This diaphragm is used to hold back particulates and long-chain organic waste water components at temperatures of up to 95 °C. In the reverse osmosis diaphragm which follows, the dissolved dyestuffs and salts are almost completely separated from the water. Afterwards, the process water treated in this way can be directly reused in all areas of the textile finishing plant without adversely affecting the quality of the end product.

Although this method has long been used in the foodstuffs and pharmaceuticals industries, it is only thanks to the use of back-flushable ceramic diaphragms which are resistant to chemicals and high temperatures that this can now also be applied in the textile industry, allowing waste water from textile production and processing plants to be filtered in reliable and continuous processes. With the aid of ultrafiltration, it is possible to protect the reverse osmosis stage effectively against contamination and thus ensure the operational reliability of the system.

Using a combination of ultrafiltration and reverse osmosis, a recovery rate in excess of 80 % of the treated waste water can be achieved. After processing with the diaphragm filtration system, the recycled process waste water is colourless, and can have COD values between approximately 100 - 300 mg/l and a conductivity of around 100 µS/cm.

In order to optimise the way in which the system operates as a whole, Benninger has fine-tuned the design of the diaphragm systems to match the composition of the textile waste water and the contaminant loads (see Table 1).

In resource management, the first step is always to optimise textile processes. In textile finishing, there are still many ways of doing this, including:

– Continuous dyeing instead of the obsolete method of exhaust dyeing
– High-performance washing units instead of simple washing units
– Optimisation of liquor flows with counter-flow and partial-flow water guidance
– Freshwater feed according to the level of contamination.

Only once the process has been optimised is a mass balance is calculated as the basis for designing a diaphragm system. Figure 3 shows a schematic view of a modern ZERO DISCHARGE textile finishing plant and the volumetric flows after integration of a diaphragm system.

Table 1: Typology of textile waste water

	Pretreatment	Dyeing	Printing
Temperature [°C]	80 – 90	40 / 60 /95	60 / 95
COD	5,000 - 25,000 mg O_2/l	1,000 - 3,000 mg O_2/l	2,000 - 15,000 mg O_2/l
Other	Size Caustic soda Washing & wetting agents Salts of earth-alkaline metals Organic impurities	Dissolved dyestuffs (reactive, direct, acids) Dye pigments (vat dyes, disperse dyes, pigment dyes)	Dissolved dyestuffs (reactive, direct, acids) Dye pigments (vat dyes, disperse dyes, pigment dyes) Thickener, salts, washing & wetting agents

Waste water free textile finishing plant

How does a traditional finishing plant perform in a case study, and what can be achieved through modernisation? Here are the most important results for the areas we looked at:

Desizing

Desizing waste water carries an extremely high COD load. At the same time, recyclable materials can be recovered by using water-soluble size. To do this, an ultrafiltration plant with temperature and chemical resistant ceramic diaphragms is required. The results are impressive:

– Water recycling: 85 – 90%
– Size recycling: 75 – 85%
– Heat recovery: 70%

Bleaching and scouring

Waste water from cotton bleaching has a high COD value due to the organic substances which accompany the cotton. This water is also usually yellow, so a combination of ultrafiltration followed by reverse osmosis is needed in order to neutralise the colour. The concentrate cannot be reused. It is subsequently concentrated even further and processed into solids or burned. Here again, the results are highly impressive:

– Water recycling: 80 – 90%
– Heat recovery: 70%

Mercerizing

The mercerizing process generates washing water with a high concentration of caustic soda of around 60 g/l. Ultrafiltration is used initially to clean and concentrate the caustic soda in the wash water and reduce its volume. Afterwards, the caustic soda is concentrated to 35 – 42 °Be using conventional evaporation methods, which allows the caustic soda to be reused in the mercerizing plant. As the conventional evaporation methods used are very energy-intensive, it is a good approach to concentrate the washing water beforehand via ultrafiltration The potential savings after this step are once again huge:

– Caustic soda recycling: 75 – 80%
– Water recycling: 80 – 85%
– Heat recovery: 70%

Dyeing

Waste water from the dyeing process has a heavy coloration and a high content of electrolytes, so a combination of ultrafiltration and reverse osmosis is required. Figure 3 shows waste water from dyeing processes which has been treated in diaphragm systems. Excellent results are achieved here again:

– Water recycling: 80 – 90%
– Heat recovery: 70%

Figure 4 shows how waste water from dyeing processes is treated in diaphragm filtration systems (1 Washing water, 2 Filtrate from the ultrafiltration stage, 3 Permeate from the reverse osmosis stage, 4 Fresh water (comparison).

Processing the concentrates

As described above, the concentrates generated in diaphragm systems can only be reused for size recycling and caustic soda recovery. In all other cases the concentrates are highly contaminated liquors. It is not possible to discharge these concentrates into rivers or lakes. For waste water free (ZERO DISCHARGE) operation of the plant, all concentrates must be thickened and solidified. The thickened concentrates can be further solidified, e.g. using evaporation techniques, or they can be burned.

Potential solutions for knitwear finishing plants are based on the same principle as the ones used for woven fabric finishing (no desizing). However, a lot more needs to be done to ensure that the methods used in knitwear finishing can catch up, particularly as the plants often use exhaust processes in jets or softflow machines. The associated water and power consumption is 2 - 3 times higher than a more modern open-width finishing system.

Operating costs

Diaphragm filtration plants run fully automatically. All of the relevant operating parameters, such as the temperature, flow rate, operating pressure etc., are controlled via PLC. Back-flushing processes and cleaning processes are started automatically.

The initial investment for ceramic diaphragms is higher than for polymer diaphragms. Thanks to their high temperature resistance and chemical resistance, their lifetime is between 5 -10 years (note: Van Clewe /D > 8 years). Conventional polymer diaphragms are used in the reverse osmosis stage, and these have a lifetime of 2 - 3 years. The operating costs for a two-stage diaphragm system are around 0.60 €/m3, which includes both the initial investment costs and the running costs of the plant. The amortisation period for a diaphragm system for textile waste water is around 2 - 3 years for water recycling and heat recovery. If the system is also used to recycle size and recover caustic soda then the amortisation period is around 1 - 2 years.

However, rising energy costs and the increased shortage of water will significantly reduce the amortisation period in future.

Solutions for passive and active protection against emissions

There is no getting away from the image of textile finishing being a major contributor to emissions. Even in the long term, it is not going to be possible to replace wet chemical methods with physical methods. This is reason enough to start looking for ways to reduce emissions. So what options for passive and active protection against emissions are available?

Passive options include:

- Process changes, e.g. continuous dyeing instead of JET treatments
- Optimisation of existing processes and recipes
- Use of highly efficient washing and finishing technologies.

The list of active options includes the use of filtration technology to recover water, energy and recyclable materials from the waste water of wet finishing plants. For the first time, the ceramic diaphragms used in the ultrafiltration stage enable reliable and continuous operation for the treatment of waste water from textile finishing processes. At the same time, they also act as a protective buffer for the downstream reverse osmosis stage, which is used for filtration of dissolved dyestuffs and electrolytes. As well as the recovery of water, energy and recyclable materials, the use of an evaporator and an evaporation plant makes it possible to run textile finishing plants which generate no waste water at all.

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