

CHAPTER 24

THE TEXTILE INDUSTRY

CHARACTERISTICS OF THE WASTE WATER

A number of processes are employed in the manufacture of textiles, most of which involve the use of water. The pollution problem is different for the various types of fibre. We must therefore distinguish between synthetic fibres, cotton and wool.

Mainly, four synthetic fibres are considered:

- a. Viscose rayon
- b. Acetate rayon
- c. Cuprammonium rayon
- d. Synthetic polyamide fibres.

The chief sources of pollution within the industry are as follows (Porter et al., 1972).

Cotton: Desizing, scouring, mercerizing, bleaching, dyeing and printing.

Wool: Top making, scouring, carbonizing, degreasing, dyeing and finishing.

Synthetic fibres: Desizing, scouring and dyeing.

Tables 24.1 - 24.3 show a characteristic analyses of waste water from various manufacturing processes (Kehren, 1958; Meinck et al., 1960; EPA, 1971).

TABLE 24.1

Waste water from the manufacture of synthetic fibres

Process	pH	Total dry matter (g/l)	BOD ₅
Cleaning rayon	8-9	1-5	2.5-3
Cleaning acetate	8-8.5	1.5-2	1.5-2.5
Bleaching acetate	9-9.6	0.5-1	0.5-1
1.washing water acetate	7-9	0.1-0.2	<0.2
2.washing water acetate	6.5-7.5	0.05-0.1	<0.2
Cleaning nylon	9-13	1.5-2.5	1.0-1.5
1.washing water nylon	8-11	0.1-1	abt. 0.1
2.washing water nylon	6-8	0.1-8	abt. 0.1
Dyeing nylon	8-9	0.3-1	0.2-0.5
Waterproofing of nylon	7-8	-	0.4-0.6

TABLE 24.1 - continued

Process	pH	Total dry matter (g/l)	BOD ₅
Cleaning orlon	9-10	1-3	1.5-2.5
1.washing water orlon	6-9	0.1-0.3	abt. 0.1
2.washing water orlon	4-6.5	0.1-0.3	<0.1
Dyeing orlon	2-7	0.1-2	0.1-1
Waterproofing of orlon	3-5	0.8-2.5	1.5-2.5

TABLE 24.2

Waste water from production of cotton fibres

Process	pH	Total dry matter (g/l)	BOD ₅
Washing	8-10	0.5-1.5	abt. 0.1
Bleaching	8-10	0.3-1.5	0.1-2.0
Dyeing	5-10	0.2-5.0	0.1-2.0
Mercerizing	5.5-9.5	2-5	<0.1

TABLE 24.3

Waste water from wool fibre production

Process	pH	Total dry matter (g/l)	BOD ₅
Degreasing with soap	9-10	40-80	10-30
Degreasing with detergents	6-8	40-100	10-30
Dyeing(ammonium sulphate)	5-8.5	7-9	0.1-1.0
Dyeing(acetic acid)	4.5-8.5	2-6	1-4
Washing	9-11	4-25	4-25
Rinsing	2-9	0.5-10	<0.1

The chief pollutants from the manufacture of acetate rayon and cuprammonium rayon are copper, sulphuric acid and ammonia, as shown in Table 24.4 (Sander, 1952).

TABLE 24.4

Chief pollutants from the manufacture of acetate rayon

Component	Acid spinning bath	Blue water
Copper g/l)	8-16	0.08-0.2
Sulphuric acid (g/l)	12-65	0.75-12
Ammonia (mg/l)	-	800-1800
pH	below 5	10

A typical average composition of cotton-mill waste water is given in Table 24.5.

TABLE 24.5

Average composition of cotton-mill waste water

pH	6-10
Total dissolved matter (mg/l)	500-3000
Volatile dissolved matter (mg/l)	300-2500
Permanganate value (mg/l)	100-2000
BOD ₅ (mg/l)	300-1200
Chloride (mg/l)	100-300
Organic nitrogen (mg N/l)	10-30
Ammonium nitrogen (mg/l)	only traces
Colour	light yellow to brown

More detailed information about the waste water from a wool and cloth mill is given in Table 24.6.

TABLE 24.6

Properties of effluents from wool and cloth mills

Components	Scouring	Cloth manufacture
pH	very high(>12)	9-11
Suspended solid (g/l)	10-20	0.3-0.7
Volatile suspended matter (g/l)	7.5-15	0.1-0.4
Dry matter (g/l)	5-10	0.5-1.5
Volatile matter (g/l)	1.5-3.0	0.15-0.40
Grease (g/l)	6-12	0.5-4.0
BOD ₅ (g/l)	1.2	0.3-1.5
Volume of sludge/ volume of waste water (%)	-	2-3

A number of additives are used in textile processing to give the final product certain properties such as washability, strength, brightness and colour-fastness.

To give an impression of the waste water problem subsequent to the use of these additives, a survey is given in Table 24.7 of the most important additives in the manufacture of cotton and the contribution of these compounds to the BOD₅.

TABLE 24.7

The most important additives in the manufacture of cotton and their contribution to the BOD₅

Additive	Consumption kg/1000 kg textiles	kg BOD ₅ /kg component	kg BOD ₅ / 1000 kg textiles
Starch	15	0.5	7.5
Carboxymethyl cellulose	1-5	0.03	0.03-0.15
Acetic acid 80%	27	0.52	14
Formaldehyde	7	0.54	3.8
Glycerin	3	0.64	1.9
Urea	13	0.09	1.2
Glucose	variable	0.7	variable
Gelatine	variable	0.9	variable
Soap	20-100	0.5	10-50
Dyestuffs	30-40	0.05-0.1	1.5-4

Many textile chemicals degrade slowly and continue to consume oxygen after 30 days. The 5-day BOD test cannot measure the ultimate BOD of the chemicals. The BOD test should be coupled with a COD test, so that the total organic material in the waste can be measured and compared with the fraction that is degradable.

Porter et al. (1976) have examined the biodegradability of several textile chemicals. The results are summarized in Table 24.8.

TABLE 24.8

Percentage biodegradation of textile chemical after 30 days

Chemicals	(125 mg/l)	Biodegradation (%)
Potassium phthalate		92
Butyl benzoate		73
Kerosene		1.1
Textile dye, direct blue 80		5.7
" " , dispersed red 68		14
" " , dispersed blue 139		5.7
" " , dispersed yellow 144		25.8
" " , reactive blue 21		1.7
" " , reactive red 21		6.3
" " , Vat violet 1		9.3
" " , Vat black 25		11.6
Urea, formaldehyde		0.48
Melamine		0.47
Glyoxal		0.18-0.50%
Textile: non-ionic polyethylene emulsion		10
Textile: polyvinyl alcohol		60

Treatment methods

The treatment of waste water from the manufacture of viscose rayons is based on recovering the substances used in the manufacturing process as far as possible. Spent sodium hydroxide is purified by dialysis. Another process with a similar aim is the crystallization of hydrated sodium sulphate from the cooled spent coagulation bath. About 75% of the sulphate in sulphuric acid and sodium sulphate can be recovered by using these methods for removing water and Glauber's salt from the spent liquids.

Considerable attention has also recently been paid to the problem of recovering and removing zinc salts. Their precipitation is possible with lime, but it can also be removed as sulphide, or by using a continuous countercurrent ion exchange system (Powlovski, 1976).

Neutralization and coagulation with lime is a most efficient treatment from the economical and technical point of view for the total waste water from the viscose rayon industry.

The main waste water problem from the production of acetate rayon and cuprammonium rayon is the recovery of copper. Precipitation was previously used, but recently an ion exchange method has been used with much success. The ion exchangers used for this purpose have shown an exchange capacity of approximately 20% copper of the dry weight (Gerstner, 1954).

Ammonia in high concentrations in the blue water can be recovered by vacuum distillation, while the washing water containing ammonium sulphate is discharged directly into the sewer system. The literature (Dean, 1961) describes that waste water from the manufacture of polyamide fibres can be treated biologically if mixed with domestic sewage in a ratio of at least 1:3.

Waste water from desizing cotton fabrics and wool scouring waste has been subjected to anaerobic digestion (Singleton, 1949). The digestion still proceeds satisfactorily at loadings as high as 0.8 kg of organic suspended matter per day per m³ of digester capacity. The COD reduction was 80-90%.

Addition of nutrients, ammonium and phosphate helped the temporarily overloaded digester return to normal operating conditions.

In order to treat cotton-mill waste water completely biological methods are employed (Bogren, 1950), usually after preliminary treatment. The best purification results are obtained by adding domestic sewage to the waste water (Jones, 1962).

Table 24.9 lists approximate data on the loading of biological equipment treating cotton-mill and domestic waste water together.

TABLE 24.8

Approximate data on the loading of biological equipment treating cotton-mill and domestic waste water together

	Filter beds	Low rate trickling filters	Activated sludge
25% municipal waste water + 75% industrial waste water	20-70 m ³ /ha	0.25-0.40 m ³ /m ³	2.5-4.0 m ³ /m ³
50% municipal waste water + 50% industrial waste water	30-100 m ³ /ha	0.3-0.50 m ³ /m ³	3-5 m ³ /m ³
Amount of activated sludge	-	-	25-30%
Air consumption m ³ /waste water treated	-	-	20-40 m ³
Preliminary sedimentation m/h	0.5	2	1.5

Fig. 24.1 is a flow-sheet for a plant treating cotton-mill waste water without addition of sewage.

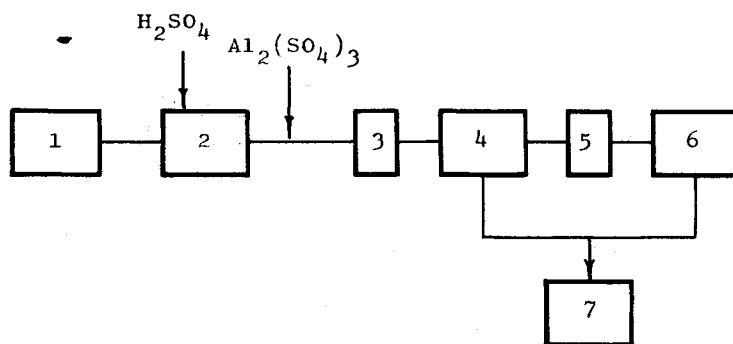


Fig. 24.1. Flow-sheet for a plant treating cotton-mill waste water. (1) equalizing basin, (2) neutralization tank, (3) flocculation basin, (4) primary settling tank, (5) trickling filter, (6) secondary settling tank, (7) sludge drying bed.

The primary treatment consists of neutralization with sulphuric acid and coagulation with aluminium sulphate. After sedimentation the waste water is passed through a trickling filter at a circulation ratio 1:5. The pH of the waste water is adjusted to 6-8 using acid. The BOD_5 reduction is 90%. If the primary chemical treatment is omitted the reduction will only be 60-70% even if the pH is adjusted.

Waste water from cotton mercerizing contains such a large amount of sodium hydroxide that recovery is profitable. The process used to this end is either dialysis or evaporation.

When treating effluents from the wool industry attention must be paid to recovery of valuable by-products.

This problem can be tackled in two ways:

The manufacturing process are modified. For example, it is possible to extract grease from crude wool by organic solvents considerably reducing the loss of this valuable material which would otherwise go into the waste water. At the same time it affords a better economy in the use of detergents in the scouring stage. By using a counter-current process for the first wool scouring stage, it is possible to achieve such high concentrations of fatty acids as their potassium salts in the waste water that it is profitable to recover them by evaporation and crystallization. Another possibility is to recover grease from scouring waste water by centrifuging, coagulation or flotation.

Grease can be processed into lanolin and potash. As much as one half or even more of the grease may still remain in the waste water after centrifugation. The grease is purified by mixing the the grease remaining in the waste water with clean water, heating to about 90°C and centrifuging.

By a combined method consisting of two stages: acidification with CO_2 and further coagulation, recovery of more than 90% is obtained. The treatment is carried out in two tanks. The waste water flows upwards in the first tank and downwards in the second (see Fig. 24.2).

The coagulant is added to the first tank. 1.25% by weight of calcium chloride is generally used (McCarthy, 1952). CO_2 is passed through both tanks from below in large excess, i.e. 2-3 times the theoretically required amount. At the same time fine bubbles of air are passed through the waste water. The sludge is filtered off on a filter after further acidification. It is possible to press the grease out of the sludge. The BOD_5 of the waste water is decreased approximately 80% by this process.

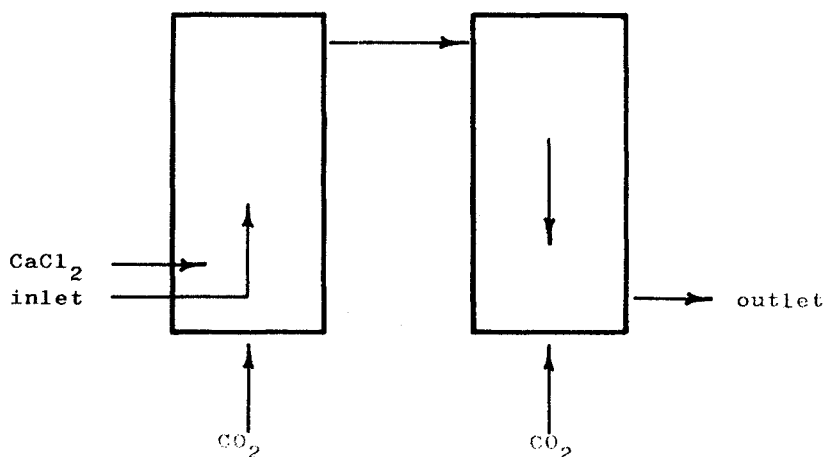


Fig. 24.2. Combined treatment of scouring waste water.

Christoe et al. (1976) have found that a combined biological and chemical treatment of wool-scouring effluents gives a higher quality effluent than straightforward biological or chemical treatment. It was found that the zeta potential decreased during the biological treatment, giving higher efficiency and a higher settling rate by the chemical step. Reduction in the zeta potential from -43 to -33 mV and from -31 to -22 mV is recorded by Christoe et al.

The waste water from the coloured-dyes house is usually difficult to deal with (Coburn, 1950) and nonbiological methods will have to be used in many instances. Dyes are just too refractory to undergo degradation in the time required (EPA, 1971).

Substantive dyes display a poor affinity for oxidation and pass into the waste water in large amounts. They are removed with difficulty due to their high water solubility (Kehren, 1957).

A relative poor decolourization of the waste water is achieved by coagulation or making it excessively acidic (Lingelbach, 1955). Coagulation treatment of dyeing waste water containing acid chrome, methachrome or sulphur dyes is possible, but requires doses of sulphuric acid as high as 300 mg/l and 800 mg/l of iron(II)sulphate, followed by the addition of alkali, 300 mg CaO/l (Porter, 1970).

Sulphur dyes cannot be oxidized easily.

Shelley et al. (1976) have investigated the treatment of textile dyeing and finishing wastes with both chemical-biological and chemical-physical systems and they found that both systems gave satisfactory results.

Furthermore, they claim that lime is superior as a pretreatment chemical coagulant in terms of both colour and for the removal of organic matter, while biological treatment following chemical pretreatment was ineffective for the removal of further colour from the waste water studied.

However, biological oxidation of chemically pretreated waste water is effective for both alum and lime systems.

Activated carbon treatment was suggested as a polishing step.

An excellent result is achieved by the so-called Katox process, which is a combination of catalytic oxidation and chemical precipitation. A 90% reduction of BOD_5 and COD and a 95% reduction of colour is obtained (Wysocki et al., 1975, and Høke, 1975).

Ion exchange has shown rather promising results for the removal of dyestuffs. By using either macro-porous ion exchangers capable of absorbing dyestuffs or by use of cellulose-based anion and cation exchangers it is possible to remove up to 90% of most dyestuffs.

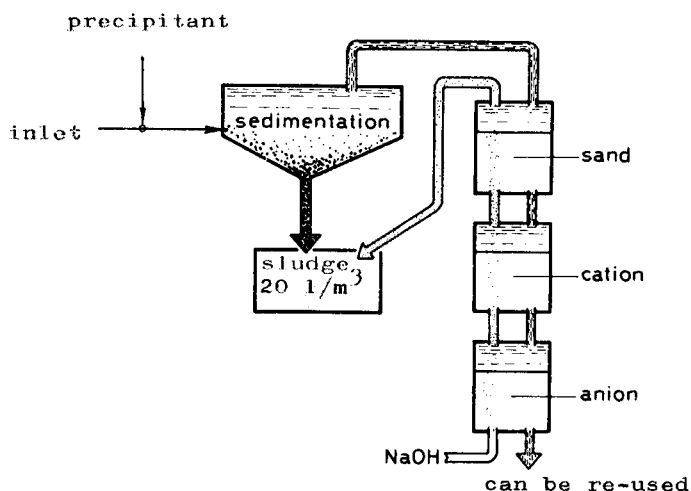


Fig. 24.3. Ion exchange combined with chemical precipitation.

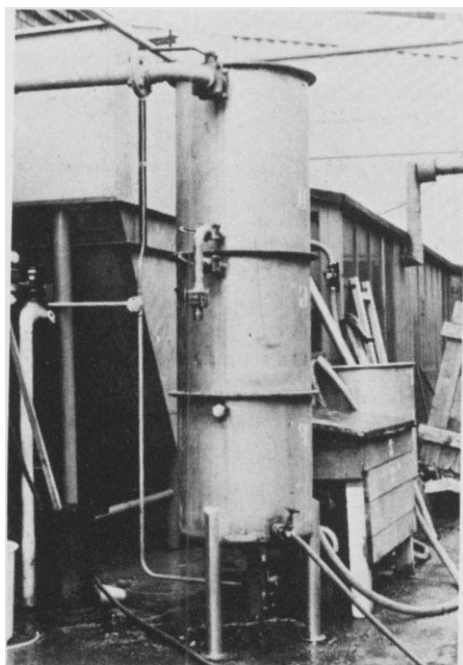


Fig. 24.4. Pilot plant testing of the combination chemical precipitation (left) and ion exchange (in front).

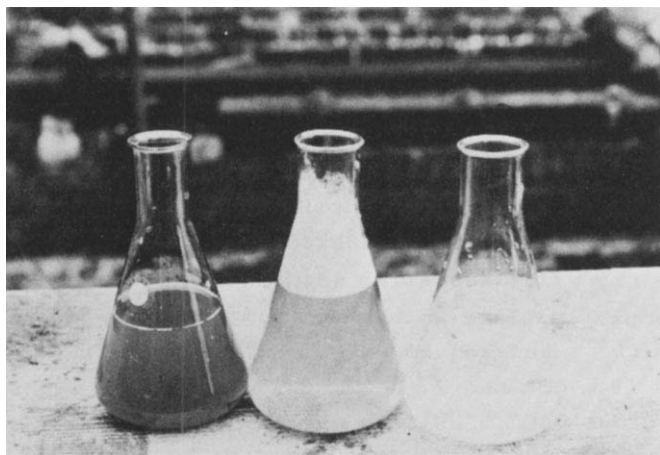


Fig. 24.5. The three samples illustrate the results of the pilot plant test. From left to right: untreated waste water from a dye-house, after first step (chemical precipitation) and after second step (ion exchange).

The ion exchange process can easily be combined with chemical precipitation, which is a useful pretreatment process (Paulson, 1971), (see the diagram in Fig. 24.3).

Netzer et al. (1975) have studied the treatment of textile mill effluent by a process consisting of lime coagulation, activated carbon adsorption, polymeric resin adsorption, ion exchange and ozonation. The results of these investigations indicate that the addition of lime can precipitate most heavy metal pollutants and in some cases achieve very good colour removal as well. Substantial removal of soluble organic compounds and colour can be attained by activated carbon and resin adsorption. Excellent removal of several dyes occurred with the weak cationic and anionic ion exchange resins. Netzer et al. recommend the use of Amberlite XAD 2 and XAD 7 resins. Ozonation was found to be very potent for decreasing colour intensity, but not for reducing the concentration of soluble organic material.

It is often profitable to purify the waste water from dye houses to an extent sufficient for it to be re-used since the water consumption is quite high.

Investigations into the use of recovered water in the dyeing processes have shown that a complete or at least partial recirculation of the water is possible.

Ultra-filtration seems to open up the possibility of re-using polyvinyl alcohol in textile processing (Auric, 1975).

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