

MEASURES TAKEN AGAINST WATER POLLUTION IN THE TEXTILE INDUSTRIES OF GREAT BRITAIN

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ABSTRACT

The majority of British textile finishing firms discharge their waste water to sewers for treatment by local authorities, and their problems are mainly those of pretreatment to render the wastes acceptable, by removal of alkali or acid, and other materials that are prohibited. Firms discharging to watercourses have to purify the waste water to a high standard before discharge and this usually involves the use of chemical or biological treatment.

Research work at the Shirley Institute over the past 8 years has been concerned with the development of appropriate methods of meeting the demands of the receiving authorities and this has involved laboratory, pilot and full scale trials on a wide variety of effluents. Sampling procedures are important on the very variable discharges and a truly proportional sampler has been devised, which is now coming into commercial production.

Water usage measurements on many textile processes have been made and the results indicate those processes where savings can be made or where comparatively clean wash waters can be recycled or used in other processes. Methods of treatment of waste water to give a high degree of purity have also been examined and these enable a substantial amount of water to be re-used.

SURVEY OF EFFLUENT PRODUCTION AND DISPOSAL

A survey made in 1963 of the textile industry in Great Britain showed that the majority of firms discharged their trade wastes to sewers for treatment by the local authority along with domestic wastes: the remainder, about 20 per cent of the firms, usually disposed of their wastes to rivers, or their strong wastes to sewers and the rest to a river. The volumes of effluent discharged covered a wide range. Out of more than 600 firms half were in the range 50 to 500 m³/day with a small number above 5000 m³/day. The waste liquors come from the wet processing of cotton, wool, linen, jute and man-made fibres in the form of fabrics and yarn, with the hosiery industry including garments and hosiery. This wet processing includes scouring, bleaching, milling, dyeing, printing and finishing in a variety of ways.

REQUIREMENTS FOR DISCHARGE

The requirements for the two principal methods of disposal are very different. For discharge to watercourses the River Authorities in England and Wales impose fairly strict limits, particularly where the rivers are used for supplies of drinking water or where they support fish. Usually the limits

are B.O.D. 20 mg/l, Suspended solids 30 mg/l, pH between 5 and 9. There are also restrictions on the amounts of toxic chemicals and metals, and a limit on temperature at the point of discharge. These restrictions demand a fairly complete treatment of the waste waters before discharge and as the River Authorities have legal power to enforce the limits, many textile works are installing or considering the requirements for treatment plants, usually of the biological type. Some firms have changed from river disposal to treatment by the nearest local authority, but this is not always feasible where the local sewage treatment works is small and the trade effluent large in volume or of high strength.

In the other method of disposal—discharge to sewers and purification by the local authority—the effluent is accepted in the unpurified form, but there are limitations on the content of such things as excess alkali or acid, sulphide, chlorine and substances that could give rise to danger to personnel, damage to drains or interference with the purification processes. The purification works has legal powers to impose a charge for treatment, usually based upon volume and strength; they take the responsibility for treatment of the wastes, but the trader has to pay for it.

EFFLUENT TYPES AND COMPOSITION

Waste liquors from the treatment of textiles contain a wide variety of substances and are usually extremely variable in composition. The textile works is performing a large number of processes, many of which are batch operations, so that at irregular intervals process liquors and wash waters of many types go down the drains. The substances in these waste waters come from both the textiles and from the chemicals and dyes used in processing. The natural fibres such as wool, cotton and flax contain large amounts of non-fibrous impurities which are removed in the preparatory treatments, together with any additives such as lubricants and sizes used in spinning, weaving and knitting. These in quite substantial quantities are in the waste process liquors, together with any chemicals employed in desizing, scouring, bleaching, dyeing and finishing. Synthetic fibres too contain lubricants, antistatic agents and other additives and these, removed in preparatory processes, contribute to the impurities in the effluent.

In textile processes water is employed to remove natural impurities and to wash out chemicals, substantial amounts being needed to keep the concentrations low and allow diffusion processes to proceed. Any reduction in water usage gives liquors that are proportionally stronger, and a limit is reached where further changes may be detrimental to the valuable textile materials. This can be against the idea of altering processes to conserve water and limit pollution.

The size of treatment plants might be brought down by water conservation, but again if toxic materials are being extracted, these must not be allowed to reach a concentration where they could interfere with the purification treatments.

Whether the impurities in the waste waters will cause serious pollution depends upon their composition. Soluble organic matter that breaks down readily in the river will be polluting because it is absorbed and consumed by

the micro-organisms present in natural water, resulting in loss of dissolved oxygen. In this category come the substances removed from natural fibres, the sizes, and some of the organic chemicals used in process, such as soap and aliphatic acids.

The waste liquors range from strong wastes such as those from wool scouring, cotton desizing and kier boiling, to weak wash waters from bleaching and scouring.

Waste waters also vary in reaction from acid to strongly alkaline, some mercerization washings containing substantial amounts of sodium hydroxide. Temperatures also fluctuate, cold wash waters merging with very hot dye liquors, sometimes at the boil.

The discharge containing such a mixture of components and changing rapidly in flow and temperature presents many problems in measurement of flow and composition, and planning for stable treatment conditions must include facilities for achieving better uniformity by mixing and balancing.

TREATMENTS AND METHODS FOR LIMITATION OF POLLUTION

In any study of a particular works effluent it is essential to obtain information on the composition of the discharges over a considerable time and simultaneously to measure the flow of liquor. The product of composition and flow gives the polluting capacity in terms of an organic load and it is necessary to regard it in this way rather than in terms of concentration only. Such a pollution load can be employed for the design of a treatment plant or for assessment of the effect on a river.

The pollution potential of the waste liquors is expressed effectively by the Biochemical Oxygen Demand (B.O.D.) and this is the most useful measure available for characterization of a waste water or for use in plant design. Other C.O.D. tests such as Dichromate Value and Permanganate Value are not so useful for assessing pollution and are unsatisfactory for use in plant design, because they respond to materials other than those which are degradable in rivers or in treatment plants. Additional information is needed on the acid/alkali balance of the discharge, the pH variation and the content of sulphide, nitrogen in various forms, phosphate, suspended solids, total dissolved solids and toxic wastes such as copper or chromium which might interfere with treatment processes or be unacceptable in the final discharge.

It is necessary to have effective sampling of these variable waste liquors before analyses are made and considerable effort has been expended on methods of obtaining specimens and mixing them to give composites that are representative of the bulk of the waste. Examination of available methods and existing automatic samplers showed us nothing that was really effective. Samplers that worked intermittently missed short flows of strong wastes, while continuous sampling at constant rate did not follow the flow pattern. To avoid these defects we developed at the Shirley Institute a continuous sampler that takes a fixed small fraction of the flow, so that the specimen obtained is similar to that in the main flow over the same period of time; at the same time the actual flow is recorded. This is a big step forward in

sampling and comparison of the results obtained by the new method with those on samples obtained by the intermittent method has shown how misleading the latter could be.

Once the flow and pollution loads are known it is possible to assess the treatment requirements and estimate the size of treatment plant with its capital and running costs. It may be helpful however to examine individual processes that give rise to highly polluting wastes, because these could cause shock loads on a plant and lead to erratic treatment. In some cases it is better to segregate these wastes and either treat them separately or add them to the main flow over a lengthy period, so that they are effectively diluted. Examples of such wastes are those from wool scouring, cotton desizing and scouring, cotton sulphur dyeing and unused pad liquors and printing pastes. Sometimes pretreatment of these by chemical or physical means can reduce their polluting load and allow the use of a smaller treatment plant for the main flow of waste water. Similar considerations apply to large volumes of weak wash liquors containing little or no polluting matter. If these can be segregated and added to the main flow *after* effluent treatment, the latter can be more effective and the plant smaller in capacity.

PRETREATMENT PROCESSES

The preliminary processes before the main treatment fall into three main groups.

- (a) Removal of waste textile materials and other gross solids.
- (b) Neutralization or removal of interfering components, such as toxic metals or excess acid or alkali.
- (c) Limitation of substances that could be dangerous or cause damage to drains or sewers.

(a) Screening to remove rags, yarn and lint is most effectively done during transfer of the waste liquors. A brushed screen or similar device permits continuous use without the need for stopping the flow to change filters. This screening is essential for natural fibres such as wool or cotton, and other spun fibres, but may not be needed where the bulk of the textile materials are from continuous filament yarns. However, a screen does prevent accidental contamination that might cause blockage of valves or sprays.

(b) Segregation of toxic metals is most effectively done at source by suitable chemical means; copper salts by treatment with iron scrap, and chromates by reduction to chromium salts. Untreated toxic materials must not be allowed to mix with the rest of the waste water.

Neutralisation of excess acid or alkali can be achieved by pH control using a suitable dosing system designed to cope with the rapid changes in flow and concentration. A simple system, with a pH glass electrode working a dosing valve, does not cope with such conditions, even with rapid stirring to disperse the additive. The difficulty in textile wastes lies in the great variations in demand, which give rise to excess being added at low flows and insufficient at times of high concentration. This is avoided by sequential dosing using two electrodes and two dosing valves. The first electrode senses, say, an increase in pH and at a given level opens the first dosing valve. If the pH

continues to rise after this, the second electrode comes into action and opens the second dosing valve, adding a larger quantity of acid until the pH falls below the limit. The two electrodes together sense the need for the larger addition and cope with large fluctuations without making the control insensitive to small pH variations.

Caustic soda, if this is not recovered for re-use, can be removed by an alternative method which is simpler in use although it requires more expenditure on plant. This is the carbonation of the alkali with flue gas, the products of combustion from the works' steam raising plant. The alkaline waste is pumped to the top of an absorption tower and trickles down over steel packing rings. The flue gas is blown in at the base of the tower and passes over the liquids, the carbon dioxide and sulphur dioxide combining with the alkali to give carbonate, bicarbonate and sulphite. The liquid emerging at the base of the tower has a pH close to 9, which gives adequate control for any subsequent treatment. Provided the tower is not allowed to run dry the gases do not cause corrosion and the structure and packing can be made of mild steel.

If there is a limitation on total sulphate in order to protect concrete structures, it may be necessary to avoid the use of sulphuric acid in the neutralization of alkalies and use other acids or carbonation.

(c) In England where trade wastes go to drains or sewers there are strict limits on the amount of sulphide that is permitted in the discharge, owing to the danger to men from hydrogen sulphide gas, and to damage to the sewer pipes resulting from the generation of sulphuric acid by bacteria. The limit may be as low as 1 mg/l of sulphur and this requires virtual elimination of sulphides from wastes such as sulphur dye residues. This can be done either by chemical oxidation using sodium hypochlorite or by aeration using a suitable catalyst to promote the oxidation.

MIXING AND BALANCING

The flow of waste liquors after pretreatment is still uneven and very variable in composition, with peak flows that can be two or three times the average. It assists subsequent purification to make the flow more uniform and at the same time to mix the liquors as much as possible in order to dilute the stronger wastes and allow any self purification to proceed. For this purpose a large balancing tank should be installed capable of taking the surges, with a constant rate of withdrawal that can be calculated from the total volume of waste in a given time.

Mixing can be done in this tank and it is desirable for textile wastes to use positive methods such as slow speed paddles, or hydraulic guns that bring the lower layers to the surface.

REMOVAL OF POTENTIALLY POLLUTING SUBSTANCES

When the waste waters have been neutralized, mixed and balanced, they are treated to remove the potentially polluting substances. Two main methods are available:

1. Flocculation with sedimentation or flotation to remove the suspended

solid matter. Not all the polluting matter is removed, but it may be sufficient for some purposes, and

2. Biochemical Oxidation in which the organic matter is consumed by micro-organisms. This gives almost complete removal of the biodegradeable soluble and insoluble organic materials.

In some circumstances a combination of the two methods may be useful, flocculation preceding the biochemical process in order to remove particular substances, or following it where thorough clarification is demanded.

1. Flocculation and sedimentation or flotation

The treatment of trade wastes by the addition of an inorganic coagulant such as aluminium or iron salts, has been in use for a long time, in many places. The effectiveness of these treatments varies with the additions made, the composition of the waste water and the method of settling, and usually the process is regarded as a means of attaining partial purification by fairly simple means.

Aluminium sulphate is most effective when the reaction of the solution is close to neutrality at the time of flocculation and, if the solution is either strongly acid or alkaline, it is essential to add suitable materials as neutralizers before or at the time of adding the flocculent. The alum of course is itself acidic and this will deal with slight alkalinity. The objective is to finish with the liquor fairly close to pH 7.

Iron salts, particularly in the ferric form, are good flocculating agents and are not so sensitive to pH conditions as aluminium salts, so that flocculation can be conducted over a wider pH range on either side of neutrality.

Under the correct conditions the flocculating agent may remove most of the floating solid particles and up to about two thirds of the soluble organic matter. This is useful if a strong waste has to be pretreated to remove part of the pollution load.

An example of the effective use of flocculation is the 'Traflo' process of the Wool Industries Research Association where the strong liquors from wool scouring are treated with ferrous sulphate and calcium hydroxide near to the neutral point. The resulting precipitate, mixed with wood flour as a filter aid, is dewatered on a vacuum filter. The filter cake discharges readily and when dry can be burned, leaving only an inorganic ash. The 'Traflo' process removes a great deal of the organic matter from the scouring liquors and that which remains can be removed almost completely by subsequent biological treatment.

In treatment of wastes from cotton scouring (kier liquors) the use of ferrous sulphate and lime can remove from 50 to 80 per cent of the B.O.D. load, but fairly large quantities of chemicals are needed to achieve this and there is an increased quantity of solids for disposal.

Apart from special processes such as those described it is possible to remove suspended matter by sedimentation in tanks. There are however difficulties in doing this continuously with textile bleaching and dyeing wastes. These liquors vary in temperature and composition which, if not balanced out previously, produce density differences giving rise to surges of liquid that carry sludge solids out of the tanks or allow segregation with

light liquids flowing through and dense ones remaining in the bottom of the tank. Fortunately, apart from wool scouring liquors, the quantities of suspended solids in textile wastes are generally small, and it is usual to omit the primary settling operation normally used with domestic wastes. The removal of the solids is effected at a later stage along with other solids produced in the effluent treatment.

An alternative to sedimentation that has recently come into use is flotation of solids induced by fine air bubbles in the liquid. This process floats the suspended matter rapidly to the liquor surface where it forms a layer which can be skimmed off. This allows removal of solids in a compact plant and the sludge is much more concentrated than that produced by sedimentation. Also the holding time is short, so that few changes occur in the state of the sludge.

2. Biochemical treatment

The methods employed for sewage purification are generally found effective for the treatment of textile wastes provided these are neutralised and do not contain any substances that inhibit the action of the micro-organisms. The organic matter in the wastes provides food for bacteria and other micro-organisms to develop, and with the oxygen dissolved in the water their reproduction is rapid. The growth of the organisms converts that part of the soluble organic matter which is biodegradeable to solid matter and carbon dioxide, leaving after clarification a liquid that is substantially free from polluting substances, although it may still contain resistant organic substances, which are essentially non-polluting. The system has to be aerated and mixed to provide a continuous supply of oxygen for the respiring organisms, and this is achieved in various ways which have given rise to different types of treatment plant.

Percolating Filter: The oldest process is the percolating filter, trickling filter or bacteria bed and this gives good purification if not overloaded.

A recent development has been the use of plastic materials that are formed into cellular structures which are used in the same way as the stone beds, but can employ much greater flow rates. Although such plants can be designed for complete purification, the greatest value appears to be in partial treatment for rapid removal of a substantial part of the polluting load. As such they can be used for pretreatment, so that the full plant can be of smaller size, or for taking part of the load off an overloaded treatment plant. The lightness permits much taller structures than with stone beds, and towers of 6 m high or more can be used effectively. They are light in weight and no elaborate foundations or walls are required. The greater heights also gives a small area, so that distribution of the liquor can be simplified. A number of types of plastic material are now available and comparisons are being made by the Water Pollution Research Laboratory at Stevenage in England.

Activated Sludge Plants: In these the organisms are suspended in liquid which flows through aeration tanks into a settling tank or flotation system, in which the biological matter is separated, the clarified and purified waste being discharged. The sludge from the settling tank containing masses of micro-organisms is returned to the aeration tanks to maintain the content of active matter. Much ingenuity has been expended on development of

economical aeration systems, the methods falling into two main classes, those with mechanical agitation of the liquid and those using air that is released well below the surface as bubbles. The mechanical aeration methods tend to lower power usage, but the air diffusion methods are somewhat more flexible with fluctuating loads. Many plants of both types are in use for treatment of domestic wastes and a great deal of experience has been gained in running these under all sorts of conditions. Comparison trials of both methods have been made on textile trade wastes and the results of these show that the wastes can be treated effectively and purified at higher loadings than are used for domestic wastes. The plants will give, under the correct loading conditions, an outfall that is acceptable for discharge to rivers, provided the feed liquor is properly neutralised and free from inhibiting substances. Textile wastes may be short of nitrogenous matter and phosphate needed for development of the organisms, and if there is a deficiency in either it must be supplemented by addition of ammonium salts or nitrates, and phosphate. The usual measure is that the ratio of B.O.D.:N:P should be 100:6:1.

The main final product from biological systems is the humus sludge from percolating filters or surplus activated sludge, and as the quantities to be disposed of are proportional to the B.O.D. loadings, these can be large. The usual methods are to concentrate the sludges to about 5 per cent solids in consolidation tanks or by flotation, and then to drain and dry on porous beds until the water content is sufficiently low for the solid cake to be lifted.

AFTERTREATMENT OF WASTES

Further improvement in the purity of waste waters can be obtained by treatment subsequent to the biological process. Interest in this comes from the possibility of re-use of the water with consequent saving on water costs or on pretreatment charges. The method of aftertreatment depends upon the residual impurities in the water and the use to which it is to be put. Usually the first objective is to remove any fine suspended solids which might flocculate and filter out on the textile materials giving dark stains. This can normally be achieved by the use of sand filters, with or without the use of a flocculating agent or absorbent. Usually the residual soluble material is resistant to biological degradation and would be removed only incompletely on further treatment. A more effective method is absorption on activated carbon, which removes dyestuffs and traces of complex organic compounds that might cause difficulties in re-use of the water. The use of granular carbon in columns is an effective way of treating the water and by using two columns in parallel one can be in use while the other is backwashed or regenerated. It is worthwhile preceding the carbon treatment by filtration or sedimentation to avoid blocking of the carbon bed with solid matter that could interfere with the flow.

None of the treatments mentioned will remove inorganic salts from the water and as considerable amounts of neutral salts are used in dyeing it is important to prevent a build up of salt by bleeding off an amount of water that keeps the dissolved salt concentration within set limits. The dyer can then make allowance for this in his dyeing recipes.

WATER CONSERVATION

Mention has been made of the re-use of water after it has been purified, but there are other ways in which considerable amounts of water can be saved. In some textile finishing processes there are large volumes of water employed for washing out traces of chemicals from fabrics. The objective is to reduce the concentration of chemical on the fabric to a low level and as this involves diffusion of the substance from inside the cloth it is a slow process and the water is only slightly contaminated. Much of the rinse water could therefore be used in other processes which are more polluted, and where the small content of chemical present would make no difference to the process. For example in cotton bleaching the cleaner waters from washing after the bleaching processes could be used in washing off after scouring where the mass of impurities removed from the cotton would swamp the small amounts of chemicals present in the other rinse waters. By systematic use of this procedure it is possible to save up to 40 per cent of the water used in bleaching cotton. The main difficulty is in providing sufficient storage for the cleaner wash waters, where they can be held until required for use.

A variation on the treatment of the waste water is to separate the cleaner wash waters and treat these by chemical means to render them neutral and inert, followed by filtration to remove solid particles and fibres. This gives a clean water supply little different in quality from the original process water, but without the outlay on treatment plant that would be required for processing the whole of the waste water. Usually the volume of wash waters is several times that of process liquors, so the amount for recycling forms a substantial proportion of the whole water usage.

Some water used for cooling dyeing machines and air compressors is quite clean and can be used directly where the increase in temperature is no disadvantage. Quite large quantities are sometimes used for cooling purposes without the works management being aware of the availability of this clean water.

In any recycling of water it must be realized that where no purification is employed the water usage at the works is lowered but the polluting load is unaffected.

Another method of water conservation that merits consideration is the use of purified domestic sewage for purposes where the small residual content of organic and nitrogenous material does not interfere with processing. It has been used in large quantities as cooling water in engineering works and power stations, but recent work in England has shown that it may be suitable for washing scoured fabric, provided the water is filtered and any colour removed by chlorination or absorption.

Pollution limitation by internal process change is restricted in textile work, as the effect on the fabric must be carefully watched. Changing the bleaching methods from the Kier boil/hypochlorite sequence to the use of peroxide and chlorite is beneficial, but much more can be done earlier in fabric manufacture by substitution of non-degradable sizes for starch products, as these are major sources of polluting matters. In wet processing, study of each treatment will show where economies can be made, and also substitutions where the organic load in the waste water can be brought down. For example

softening of water and the use of the bare minimum of soap will make a difference, as will the change from acetic acid to formic acid or even to mineral acid, in some processes. The cumulative effect can be appreciable.

Probably the most effective approach to this method of pollution control is to take the yearly list of chemicals and textile auxiliaries used at the works and convert the total weight of each one into its equivalent in B.O.D. This will show immediately where the major sources are, and changes to more innocuous materials will often give a marked reduction in the pollution load. Each firm has to work out its own methods for such changes, but it is well worth the time spent.