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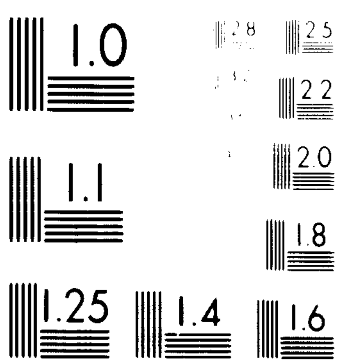

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MODERN METHODS OF EFFLUENT DISPOSAL 1/

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INTRODUCTION

In this paper I shall deal with textile trade effluents, their character and their effects upon the environment, together with water supplies and usage. The effects on receiving waters are related to the main sources of pollution which come from both the fibres and the chemicals employed in processing. Selection of the chemicals and economy in their use can diminish some adverse effects, and treatment of the effluents using biological, chemical and physical methods, can prevent pollution. The economics of the treatment of wastes and of water conservation are related to one another, and are also bound up with the limitations imposed by the Water Authorities.

I. THE IMPORTANCE OF ENVIRONMENTAL FACTORS

The textile industry converts natural and synthetic fibres into fabrics for domestic and industrial use during which the impurities are removed and many chemical and mechanical processes employed to give the required feel, colour or physical properties of the finished article. In the course of this processing, large quantities of water are employed which carry away the used chemicals and the impurities. These may have a bad effect upon the water into which they go and may give rise to objections on the grounds of pollution, leading to penalties, charges for disposal and restrictions upon the textile processor.

It is useful to consider a simple example of, say, a discharge from a works that is bleaching and dyeing cotton fabrics. Take a works that is handling 20 tonnes of cloth per day, using about 5.000 m^3 of water for the various processes. The effluent will carry away about 2 tonnes of impurities, mainly organic matter and will have a Biochemical Oxygen Demand (Or BOD) of 200 mg/l or more (1). The BOD can be regarded as a measure of the polluting effect of the effluent on the river; a low value is good, whereas a high value is bad, a clean river having a BOD of around 2 mg/l and a dirty one 20 mg/l or more. The discharge will cause pollution if it increases significantly the BOD of the river. Often a limit of 20 mg/l is imposed on the discharge to a river, so that if it is diluted 10 times or more, the BOD of the stream is not increased by more than 2 mg/l. In the river, the BOD will diminish naturally through self-purification, and as it goes on its course, the water will slowly revert to an acceptable figure. If much greater dilution is available, say 100 fold, the river would be able to accept a somewhat higher BOD in the discharge, providing no other substantial contaminating discharges were in the vicinity.

Coming back to our example, the contaminating load can be expressed in another way, that is, population equivalents. In this form, the pollution load from the textile works is equivalent to that from a town of 16.000 inhabitants. The textile works may employ about 500 workpeople, but from the environmental aspect, the works is equivalent to 32 times that number. These examples will give some idea of the scale involved; the actual values in any particular case will depend upon the operations carried out in the dyeworks, the types of fabric, the sizes used in weaving and the methods of treating the effluent before discharge. Some places may employ more water for a given weight of cloth processed, and this will result in a weaker effluent, although the load (i.e. the weight) of contamination will not be affected very much; twice the volume at half the concentration leaves the weight of material unchanged.

In this effluent, more than half the organic matter comes from the natural impurities in the cotton and the sizes used in weaving, these being taken out in the desizing and scouring operations. The rest of the organic matter comes from the chemicals and textile auxiliaries used in the various processes of bleaching, dyeing and finishing. If there is need for reduction in the pollution load, it must be remembered that the part coming from the fibre impurities cannot be altered very much. The preparatory processes are intended to remove these from the fabric and they have to be disposed of down the drain. Any diminution of the load must therefore come from changes in the sizing materials or in the chemicals employed in the various processes. This will be dealt with in more detail later.

Another aspect that merits consideration is that of the water itself; this should be treated as a service commodity, just as one would treat steam or electricity. We can divide the problems of water supply and disposal into several sections, thus:

a. The water source. Textile processing needs a constant and uniform supply of good quality water. For this, it is often in competition with other industries and with those requiring sources of potable water. In the case of some properties such as hardness and the content of suspended matter, the requirements of textile works are often stricter than those for potable supplies.

b. Purification of the water. For many purposes, the water is softened usually by the base exchange process, or naturally soft water may require filtration to remove fine suspended solid particles. From ground water it is essential to remove any dissolved iron and manganese.

c. Distribution. The water has to be distributed to the process machines in the works, and supplies arranged so that there is no shortage at times of peak loading. In a bleach works, the peak flow may be three or four times the average flow.

d. Disposal. After use, the water is discharged although fairly clean wash waters can be used again, where the small content of chemicals and organic matter is not detrimental. In circumstances of severe water shortage, it is possible to purify most of the waste water and recycle it, discarding the most heavily contaminated liquors.
The final discharge may be to a watercourse, the sea or to the sewers of a town where purification is effected in the sewage works.

Organic pollution has several effects upon the water receiving it, but the main one is that of providing food for micro-organisms. In using this food for growth and movement, the organisms consume oxygen of which there is only a limited amount dissolved in the water, about 8 mg/l (or parts/million). The oxygen is also needed by animals, fish, insects and plants in the water, and with any serious loss, these will die. In bad cases, where there has been loss of all the dissolved oxygen, the stream becomes septic and bad-smelling, devoid of fish and supporting a very limited amount of aquatic life.

Toxic materials will also kill micro-organisms and other aquatic forms, upsetting the balance of life in the river.

By control of the volume and concentration of the effluents entering a stream, it is possible to keep it in good condition and allow the continuing support of the many creatures in it.

In the discharge of an effluent to a watercourse, it is usually necessary to purify the waste to an extent dependent upon the regulations for the area. These may require a reduction in the BOD, as mentioned earlier, but also may restrict suspended matter, temperature, alkalinity or acidity and substances that could be toxic to the flora and fauna of the stream. Also in this country there have been limitations upon the content of nitrogeneous matter, and soon will be upon the content of phosphate. These latter are intended to control the toxic effects of nitrogen compounds and curb the unwanted growths of algae in surface waters.

II. THE USE OF CHEMICALS AND THEIR EFFECTS ON POLLUTION

It is important from the environmental aspect to keep to a minimum the quantities of those chemicals and other materials which finish up in the effluent, particularly those which have to be employed in substantial amounts and which can increase pollution. They may be grouped for study into three classes:

a. Organic substances that increase pollution directly or indirectly.

b. Inorganic substances which cause pollution or upset the ecology of watercourses.

c. Toxic substances, both organic and inorganic.

As examples of the first group, a., we can take starch products, organic acids and urea. Limitation of quantities or substitution by less degradable materials should be kept in view at all times. Organic acids, particularly acetic, contribute a good deal to the pollution load, and sometimes can be reduced in quantity or replaced by inorganic acids or salts. Urea and other nitrogeneous substances contribute to the nutrition of micro-organisms and may have to be controlled.

In class b., products that cause difficulties are ammonia and soluble sulphides. Ammonia for the same reason as urea, and sulphide because of its toxic properties and strongly reducing character. Sulphides can give rise to unpleasant smells and cause damage to concrete and brickwork.

Class c. contains toxic materials such as copper salts, chromium compounds (particularly chromates), chlorinated substances and, again, sulphides which with acids can give a dangerous gas.

Copper and chromium compounds if used should be treated before disposal so that they are made relatively innocuous. Chlorinated substances should be kept out of draine. Sulphides, commonly used in dyeing, are severely restricted, the larger towns in this country limiting it to between 2 and 4 mg/l (parts/million), especially where the sewers are large; there have been several cases where men working in sewers have been killed after the chance mixing of sulphide with an acidic substance. A method is now available for the oxidation of sulphide to render it innocuous before discharge.

Changes can be made to less polluting materials, but where this is done, they must be as effective in the textile process as those that they replace. In this country and some others in Europe, the synthetic detergents have been changed from 'hard' to 'soft', from non-biodegradable to biodegradable. Here biodegradable means capable of being broken down into simpler products in the biological process employed in the sewage works. Here, where a 'hard' product is replaced by a 'soft' one, the latter must be no less effective in the textile processes in which it is used - and preferably, no greater quantity should be required.

It is a worthwhile exercise to study the list of chemicals used in a works and to consider whether any of them can be reduced in quantity or replaced by other materials where the usage may be smaller for the same work, or where the potential pollution is reduced. Often, substantial savings can result, but this exercise is only valid if both aspects are known - that in the textile process and that in the effluent, so that comparisons with any alternative products have some meaning. Many chemical manufacturers nowadays can provide information on the biodegradability of their products, and this is very useful.

There is not much information available on the toxicity of materials, and our Water Research Centre, at Stevenage, has been collecting information on this and establishing a register of substances that show toxic effects in biological treatments and in watercourses.

III. TREATMENT OF EFFLUENTS

Purification of textile effluents can be achieved in several ways, usually by a sequence of operations, and it may be partial or complete according to the requirements of the authorities controlling the receiving water. Partial treatment may be sufficient where the waste is discharged to a sewer, whereas full treatment is needed where strict controls are imposed on a waste entering a clean river. The combination of processes required depends upon the character and variability of the effluent itself.

The preliminary or partial treatments may include the removal of prohibited substances or groups of materials, or to reduce the total load where there is a limit on the polluting load that can be discharged.

Thus, excess alkalinity can be neutralised by an automatically controlled addition of an acid. A pH probe in the effluent system actuates a controller so that when the pH level is high (that is, the solution is alkaline), an addition of acid is made until the level is brought down. For accurate work this method may not always be sufficiently precise. A better method is to allow the pH probe to control a small acid addition, and when persistent alkalinity shows this to be insufficient, a second control comes into action, adding further acid to neutrality. This addition in sequence gives good pH control in practice. In a similar way, acid effluents can be neutralised by the addition of lime, soda or other cheap alkali.

For large quantities of caustic alkali, such as those from mercerisation rinses, the neutralisation can be obtained with flue gas, employing the carbon dioxide that it contains as the acid. The alkaline liquor is pumped to the top of a tower filled with cellular packing, and trickles down to the bottom, meeting an upward flow of excess flue gas. The absorbed carbon dioxide converts the sodium hydroxide and sodium carbonate to sodium bicarbonate with automatic control close to pH 9 which is almost always acceptable.

The kier liquors from cotton scouring can be highly polluting, but they can be successfully treated by biochemical methods. It is however important to neutralise them first to get rid of the residual alkali which they contain.

Another pretreatment that is effective is the removal of sulphide by direct controlled oxidation by means of fine bubbles of air passing through the liquid contained in tall vessels. This converts the sulphide into thiosulphate which is much less toxic, and this is usually acceptable when the liquors receive further biological treatment by the local authorities.

Normally, textile waste liquors contain a fair amount of fibre, lint and rags, and to avoid blockage of pipes and valves in the treatment plant, it is worthwhile to remove this by a suitable screening process. Of particular value for this is the brushed screen, a half-cylinder of perforated metal, through which the liquor flows but retaining the solids. Slowly revolving brushes remove the lint and rags from the perforated metal surface and deposit them over the side for collection and removal.

We come now to the general treatment of effluents to purify them by removal of soluble organic matter that can cause pollution. The methods can be biological, chemical or physical, or a combination of these, and the choice depends upon what are the requirements for the final discharge and, of course, upon the constituents of the effluent.

Biological processes consist mainly of contact between the liquors and masses of micro-organisms, mainly bacterial, in the presence of excess air. The micro-organisms absorb the soluble organic matter and (if it is biodegradable) convert it to carbon dioxide and to simple substances which they can use for growth and reproduction, utilising some of the dissolved oxygen in the process. In effect, it is a concentrated version of what can happen in a river in its self purification, but with the high content of micro-organisms, the organic matter is removed in hours instead of days.

There are two main biological processes, one the so-called biofiltration and the other the activated sludge method.

In biofiltration, the waste flows over the surface of solids in a thin film exposed to the atmosphere. On the solid surface grows a film of micro-organisms which absorb organic matter from the liquid and utilise it as food. An example is that of beds of broken stone sprayed with the effluent, and this is the same process as the percolating or trickling filter of the sewage works. A modern development is the cellular plastic medium inside a tower down which the effluent flows, and this has a much higher capacity per unit volume than the ordinary percolating filter.

The other main process is the activated sludge method, which was invented and developed in Manchester between 1912 and 1914, and used ever since in sewage works all over the world. In this process, the micro-organisms are in large, intensively aerated tanks through which the waste flows continuously. The bacteria are floating in the water, free swimming or in clumps, not anchored to a surface as in the previous method. The liquid passes on to another vessel and is clarified by separation from the suspended matter, usually by sedimentation. The sludge that settles out contains most of the live bacteria and other organisms, and this 'activated sludge' is returned to the aeration tank for further use. By this means, the high concentration of bacteria essential for the operation is maintained. The sedimentation process is an essential part of the treatment in order to separate the purified liquid from the solids which contain the residues of the impurities which were originally in the effluent. Recently, an alternative method has been developed, that is flotation of the solids to the surface from which they are removed by means of a suitable scraping device. In this method, fine bubbles of air or gas are produced by a variety of means, and these become attached to the solid particles, causing them to float and coagulate. One advantage of this method is the smaller space needed compared with that required for sedimentation tanks.

Chemical treatment of wastes may be with materials that react directly upon components of the liquor or, indirectly, by the formation of flocculent precipitate which adsorbs or entrains material from the waste, and the resulting solids are separated by mechanical or physical means. As an example of the former, one can take the reduction of dichromate with bisulphite and subsequent removal by increasing the alkalinity to precipitate chromium hydroxide. Other methods that involve flocculation as a means of purification are common as, for example, in the use of iron or aluminium salts, which in neutral or alkaline conditions give rise to their insoluble hydroxides which coagulate and carry down organic matter. Iron salts can also react with any soluble sulphides, producing a precipitate of black ferrous sulphide which may be useful in removing small or moderate amounts of sulphide; larger amounts are better dealt with by oxidation.

Physical methods are used for liquid/solid separations which include sedimentation, centrifuging (an accelerated sedimentation), flotation and filtration. The choice of method is dependent upon the amount and character of the solid particles; thus sedimentation or filtration might be used for large volumes of water with a small or moderate content of solids, while centrifuging might be employed for a small volume containing a high content of solids such as a sludge. Evaporation can also be used for complete separation of water from its contained solids, both soluble and insoluble; this is usually only practicable for concentrated wastes, for toxic materials or for very highly polluting liquors.

Physical removal of low concentrations of soluble materials can be achieved by the employment of active carbon. This material has a high porosity having an extremely high internal surface, and soluble matter is adsorbed on this surface and strongly retained. The process is suitable for removal from effluents of substances that are difficult to extract by other means such as residues of soluble dyestuffs, phenolic materials and chlorinated compounds. As a whole host of other substances are adsorbed at the same time, it is preferable to use the method upon a liquor that has already been partly purified, so that better advantage can be taken of its special features. Two principal methods are used: one with powdered carbon added to the liquid and separated after a given contact time, and the other by passing the liquid through beds of granular carbon. In the first method, the used carbon is discarded after use, while in the second, the carbon when saturated is dried and regenerated for further use.

Selection of the process or processes most suitable for a particular effluent can be very difficult owing to the many factors that affect it. It depends upon the composition of the waste, its variability, the scale of working (both volume and load) and the limits that have to be met on discharge. If the principal requirement is the removal of organic matter, then usually a biochemical process will be effective, and selection of the appropriate method will depend upon local conditions.

Sometimes, where a high degree of purification is demanded, it might be necessary to employ two processes in sequence, such as for example an activated sludge unit or a high rate biological filter taking out the bulk of the organic matter, followed by a percolating filter or an active carbon unit to take out most of the remaining organic matter. In any system, effective removal of fine solid particles in the later stages is very important, because a high proportion of the residual organic matter in a treated effluent is often in the suspended matter that has not been removed in clarification.

If substances are present that interfere with a biological process, either by their toxicity or by some physical effect, it may be necessary to use a chemical treatment first, to remove the offending substance, and then to follow with the biological process.

On the other hand, there may be substances which pass through the main treatments unchanged, such as non-degradable auxiliaries or dyestuff residues; these, if soluble, might be taken out with active carbon. The type of material that causes most difficulty is that which is in a finely dispersed state, but inert and resistant to flocculation so that it tends to pass unchanged through all the usual processes.

IV. ECONOMICS OF TREATMENT OF EFFLUENTS AND OF WATER CONSERVATION

This subject is bound up with the requirements of water authorities and the availability of water of a quality suitable for textile processing. Textile treatments use large quantities of water in the various processes and employ it to carry away impurities from the textile fibres, sizing materials from the fabrics and used chemicals from the treatment baths. If ample water were available, and if disposal could be made to the sea in deep water, there would be no point in the purification of waste water. However, such conditions are almost unknown. Usually, the textile firm is in competition for water with other firms and with potable water suppliers. The disposal may be to a watercourse where the effluent could contaminate the water and affect users downstream before self-purification can come into play. These factors bring the need for conservation of the available water and the limitation of quantity and quality of the discharge so as to avoid interference with other users.

Coneervation of water involves the sconomical use of the supply, so that the water consumption is adequate for each process, but not wasteful. An extensive study has been made in this country of textile water usage, and this has shown the average to be expscted for most of the wet processes and ths ranges of values found, ths excessivsly high figures showing where economies could usefully be made.

In addition, water can be reused in ssvsral ways giving fur+hsr econo-mise:

a. Collection of cooling water and uss in process washing.

b. Taking fairly clean wash waters from one process and using them in another where strong liquors are employed and the small content of impurity from the first process does not interfers. By this means, it may be possible to save up to 40% of the total water usage.

c. Partial treatment of some of ths less contaminated parts of an effluent, say by flocculation and settlement, can give additional savings up to about 60% of the total. This water must bs used in selected processss whsre the added salts do not intsrfers.

d. Full purification of the whole effluent looks attractive if it would allow all the water to bs reused, but this cannot be realised in practice. In the effluent, thers ars some matsrials such as soluble inorganic salts, which ars not removsd in normal effluent purification processss and would incrsase in concsntration with each cycle of use. High levsls would intsrfere with many dyeing processes, so the amount would havs to bs limited. This limit would have to be maintained fairly closely and would require discarding some of the wasts water and blending with fresh water. It would involvs about 20% of the total water and so limit recycling to not more than 80%. Also, othsr components such as traces of optical brightening agsnts can affect dyed shadss, and toxic organic materials could accumulate and upset the purification processes.

In the majority of casee, it would not be worthwhile to incur the large expenditure for full treatment solely to allow the reuse of another 20% of the weter. The situation where it might be considered ia that where a full treatment would have to be employed to meet discharge limitatione, and then some modifications or additione made to allow recycling of the bulk of the water with speciel treatment of the more concentrated reeidue.

To sum up on the aubject of water conservation, there are a number of ways in which various amounts of water can be recycled, and these become more difficult and more expensive as the amounts increaee. Every cese for water reuee hae to be studied individually becauee so many conflicting fectors have to be taken into account in order to devise the solution that is the beet for the apecial circumstances of the textile proceesor.

We can now move from initial use of water to its final disposel. Generelly this ie in two parts, the main effluent discharge conteining in a large bulk of water small reaidues of material, and a semi-solid sludge containing ell the materials, soluble and insoluble, thet were in the raw waete, changed in form but still substantial in amount. The weight of the aolide in the sludge can be teken as roughly helf the BOD load of the original effluent. Some of the organic matter will have been loet to the atmosphere ae carbon dioxide emanating from the biological processes, and some added inorganic matter may come from coagulation treatmente, but it ie ueeful to conaider the semi-aolid eludge as the final form of the impuritiea that were in the effluent. The diaposal of this eludge forma no emall pert of the discharge procees. Ueually, it contains 95% or more of water, and dewatering it to give a handleable eolid with a water content of eay 60 to 70% requirea equipment and a method of final disposal. The cost of ell this is roughly of the seme order ae the cost of the biologicel treatment itself.

The ecele of working is more readily eeen if we take an example of a dyehouse waete of, say, 1.000 m^3/day with a BOD of 400 mg/1, thet is a BOD load of 400 kg/day. After various treatments, the effluent is discharged with a BOD of 20 mg/1, and the 400 kg of degradable orgenic matter ie converted to give 200 kg of solids in, eay, 4 m^3 of sludge

(5% solids). This sludge on dewatering gives 0,5 m^3 of solid residuea (40% solids) and 3,5 m^3 of water which goes back for treatment as it contains some organic matter.

An alternative method of diapoaal is the use of partially treated effluent for irrigation. For this, the waste must be neutralised, be free from toxic matter and have a low salt concentration. For thia end uae it would pay to segregate dye liquors with high salt content and other highly contaminated liquors and dispose of these elaewhere. The biological sludge can also be deposited on land, and this offers a simpler and cheaper method of disposal than that of going through the operationa of dewatering.

One advantage of recycling water ia that the raw water hsa to be softened, whereas the recycled water is already substantially free from calcium and magnesium, so that there would be a aaving on the softening costs which would be helpful with some hard water suppliea.

A disadvantage is the need for storing the recovered water and maintaining a aervice aystem entirely separate from the original process water supply. Storage facilitiea are essential with reuse of fairly 'clean' wastes, but these can usually be piped to a few aelected machines, and distribution is not difficult. With partial treatment, storage becomes less important, but distribution lines must be kept separate. Where purification ia practically complete, the need ia for storage of the untreated wastes, but diatribution can be through a single system, with possibly a limited pipe aystem of unused water for specisl purposea. In plant design, it pays to have both the water supply and drainage systems easily accessible, and capable of being altered readily to allow variations in methods of use. It also pays to have facilities for measuring flowa incorporated, so that the worka engineer knowa exactly what water ia being used and where.

SUMMARY

Textile finishing works use large amounts of water and discard these as effluents which contain impurities from the fibres, the sizing materiala and the various chemicals and auxiliaries used in wet processing. Water should be regarded as a service commodity that has to be purified and used

economically and which on discharge carries away unwanted materials that could cause river pollution if preventative steps are not taken. Pollution of streams results from contamination with organic matter that acts as food for micro-organisms which consume oxygen in the water and interfere with other forms of life, or by toxicity cause damage to the flora and fauna in streams. Preventing this by biological or chemical treatment of the effluents converts the wastes into solid residues that can be discarded. Water conservation is bound up with the conditions of application of water and with the disposal of wastes, and methods are indicated for saving substantial amounts of water.

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