CASE STUDY OF TREATING TEXTILE EFFLUENT

BY

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End-of-pipe Treatment Methods

Once waste minimization has been carried out in the factory, effluent will still be produced that will require some form of treatment prior to disposal to sewer, river or sea. This appendix will summarise the available technology for treating textile effluent for colour removal.

4.1 Effluent Segregation

Prior to the installation of any end-of-pipe treatment method, it is essential to carry out segregation of the effluent streams to separate the contaminated streams from the relatively *clean* streams for treatment. This result in a more effective treatment system as a smaller volume of waste water is treated (resulting in lower capital and operating costs) and it allows for the use of specific treatment methods rather than trying finding one method to treat a mixture of waste with different characteristics. The segregated *clean* streams can then be reused with little, or no, treatment elsewhere in the factory.

A4.2 Treatment Technologies

There are 2 possible locations for treating the effluents, namely, at the textile factory or at the sewage works. The advantage of treatment at the factory is that it could allow for partial or full re-use of water. The following technologies have all been used:

w coagulation and / or flocculation membranes (microfiltration, nanofiltration, reverse osmosis), w adsorbents (granular activated carbon, silica, clays, fly ash, synthetic ion-exchange media, natural bioadsorbants, synthetic bioadsorbants), w oxidation (Fenton's reagent, photocatalyis, advanced oxidation processes, ozone) and w biological treatment (aerobic and anaerobic).

Since the effluent from the textile industry is complex and variable, it is unlikely that a single treatment technology will be suitable for total effluent treatment and water recycling. A comprehensive review of these technologies is given by Southern (1995).

A4.2.1 Coagulation and/or Flocculation

Chemicals are added that form a precipitate which, either during its formation or as it settles, collects other contaminants. This precipitate is then removed either through settling or by floating it to the surface and removing the sludge. This is a well-known method of purifying water. Both inorganic (alum, lime, magnesium and iron salts) and organic (polymers) coagulants have been used to treat dye effluent to remove colour, both individually and in combination with one another. With the changes in dyes and stricter discharge limits on colour, inorganic coagulants no longer give satisfactory results. They have the added disadvantage of producing large quantities of sludge. Organic polymers show improved colour removal and produce less sludge, but then may have detrimental effects on the operation of the sewage works. Cationic polymers have also been shown to be toxic to fresh water fish.

Alum is effective in removing colour from textile effluent containing disperse, vat and sulphur dyes, but is ineffective against reactive, azoic, acid and basic dyes. However, it does have the advantage of reducing phosphorous levels, thereby improving the operation of sewage works.

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A4.2.2 Membranes

The membrane methods that are available for effluent treatment are microfiltration, ultra filtration, and nanofiltration and reverse osmosis. In general, nanofiltration or reverse osmosis are the most effective processes for removing colour and recovering water. The drawbacks of these processes are the high capital costs, the fact that the concentrated effluent still has to be treated, and membrane fouling.

The most frequently tested method is reverse osmosis. The effluent is forced under moderate pressure (1.5 to 4 MPa) across a semi-permeable membrane to produce a purified permeate and a concentrate. This process can remove up to 99% of salts and the complete removal of most organic compounds. The concentrate will require further treatment prior to disposal as the level of impurities are up to six times that of the original effluent stream.

In nanofiltration, the membrane acts as a molecular filter, retaining polyvalent ions and compounds with a molecular mass greater than 200. The concentrate contains almost all of the organic impurities and a large proportion of the polyvalent inorganic salts and requires further treatment prior to disposal. The permeate contains the monovalent ions (e.g. Sodium and chloride ions). This method of effluent treatment has been found to be effective in the treatment of dye baths from reactive dyeing where sodium chloride is used as the electrolyte, as the permeate produced contains the salt and is virtually colourless, and therefore, suitable for reuse in the reactive dyeing process, saving both water and the cost of the salt.

Ultrafiltration and microfiltration as stand-alone treatment methods are only suitable for reducing COD and suspended solids from solution. They are effective in combination with other treatment methods such as coagulation/flocculation. They are also useful for the partial removal of colour and organics prior to discharge to sewer. Microfiltration removes colloidal material such as disperse and vat dyes.

A4.2.3 Adsorbents

In order for an adsorbent to work effectively, the concentration of the impurities in the effluent stream must remain fairly constant to prevent the release of the adsorbed material back into the effluent if the concentration falls.

Activated carbon is the most commonly used adsorbent and it is effective in removing organic components from the effluent (but not inorganic compounds). Once saturated, it must be regenerated or disposed of. Regeneration is costly, and in most cases it is trucked off site and disposed of in landfill. Care must be taken with the disposal method as the organics may leach out over time and cause pollution problems at a later date. Other adsorbents include inorganic compounds such as silica, cinder ash and various clays. Trade name adsorbents such as Macro-sorb and COLFLOC have been shown to be effective at removing colour from reactive dye bath effluent, although disposal of the sludge may be problematic.

Bioadsorbants are naturally occurring polymers that are biodegradable and have structures that allow the adsorption of species within them, or which act as ion-exchangers. Synthetic cellulose bioadsorbants have also been developed and preliminary investigations into their use for removing colour due to reactive dyes show promising results (Southern, 1995).

A4.2.4 Oxidation

Oxidants decolourise dyes by breaking down the dye molecule. Commonly used processes are ozone and Fenton's Reagent.

Ozone has been investigated in a number of studies. It has been found that dye wastewaters react differently depending on the composition. Effluent containing sulphur and disperse dyes are difficult to decolourise, whereas colour due to reactive, basic, acid and direct dyes is removed fairly easily. The main drawback with installing an ozonation plant is the high capital and operating costs. However, improvements in generator and contacting equipment design, together with increasingly strict environmental legislation will probably lead to a more widespread application.

Fenton's Reagent consists of ferrous salt (usually sulphate) and hydrogen peroxide. The reaction is carried out at a pH of 3 and involves the oxidation of ferrous ion to ferric ion with the simultaneous production of the hydroxyl radical. This radical is a powerful oxidising agent and will attack organic compounds and cleave the bonds. In the case of dye molecules, this would lead to decolourisation. A disadvantage (in terms of costs for the discharger) is the production of ferric hydroxide sludge, but it is thought that this sludge is advantageous to the biological treatment system.

Other oxidation methods include the use of ultraviolet light in conjunction with a photo catalyst (titanium dioxide), or other chemical agents such as hypochlorite (the use of which is not encouraged as chlorinated organic species may be formed which are themselves toxic to the environment).

The main drawback of these above methods is that it is not known what degradation products are formed from the oxidation process and it may be the case that these end products, although colourless, may be more toxic than the original dye molecules.

Aerobic treatment

The majority of sewage works are based on the principle of aerobic treatment, where the incoming effluent is exposed to bacteria which convert the components into carbon dioxide and sludge, which is then sent to an anaerobic digester for further treatment. It has been found by a number of researchers that aerobic treatment methods are not sufficiently able to treat the colour from the textile industry, and any colour removal that does take place is due to adsorption onto the sludge, rather than degredation of the dye molecule.

Anaerobic digestion

Anaerobic digestion is the biodegradation of complex organic substances in the absence of oxygen to yield carbon dioxide, methane and water. It is an effective process for treating high COD wastes (e.g. size, desize washing and scouring) and the methane that is produced can be utilised as energy for heating etc. The reducing conditions in an anaerobic digester have been found to cause decolourisation of azo dyes through cleavage of the azo bond

Table A4-1 : Summary of available textile effluent treatment technologies			
Coagulation/ flocculation	alum lime iron polyelectrolytes	* simple equipment * relatively rapid colour removal * significant reduction in COD	* large volumes of sludge may be generated * continual addition of chemicals * high running costs * carry-over of polyelectrolytes may affect sewage works * product generally unsuitable for reuse * will nor remove reactive dyes * precise pH control necessary * simple equipment * relatively rapid color removal
Membranes	reverse osmosis filtration ultra filtration	* removes impurities of particular molecular masses * good color removal * fast * can handle large volumes * removes ions	* high capital costs * some effluent cannot be treated * concentrate contains almost all impurities * concentrate must be treated by another technology prior to disposal * impurities in purified stream may be too high for re-use * regular cleaning is required * pretreatment required * precise pH control necessary
	Dialysis or continuous deionization	* purified stream could be re-used * cation stream could be re-used to regenerate water softener, or as caustic or carbonate in the dyeing process	* portion of the effluent is not treated * concentrate contains almost all impurities * at least one of the concentrates must be treated by another technology * organic material could foul membranes * non-ionic species are not removed * capital and operating costs not known

Adsorbents	**activated carbon, silica, charcoal, peat, synthetic polymers etc.**	*** good colour removal * simple technology * low operating costs for some adsorbents * removal of solvents**	*** high capital costs * slow * regeneration or disposal costs * no single adsorbent is suitable for all dye types * required dosage may be high**
Oxidation	**Ozone Fenton's reagent UV/peroxide UV/catalyst Chlorination**	*** good colour removal * can handle large volumes * rapid decolourisation * simple operation * sludge enhances sewage work operations * good colour removal * powerful oxidant * effective at destroying organic compounds * inexpensive * chlorinated byproducts**	*** high capital costs * high operating costs * not effective at removing colour from all dye types unknown oxidation products * unknown oxidation products * high running costs * high capital costs * unknown oxidation products * good colour removal**

Reduction	**tin chloride hydrosulphite**	*** good colour removal * effective for decolourising azo dyes**	**aromatic amines may be formed * incomplete degradation**
Biological	**Aerobic Anaerobic**	*** suitable for removing colour due to insoluble dyes * usually results in mineralisation of dyes * non-specific colour removal * decolourises most dyes through reduction mechanism * methane produced can be used energy on-site**	*** does not remove colour due to soluble dyes such as reactives * large volumes of sludge are generated * Unknown degradation products. * high capital cost unknown degradation products * high capital cost**
Evaporation		*** concentrates effluent stream * product water suitable for reuse**	*** does not "treat" colour * high capital costs * high operating costs**
Irrigation		*** inexpensive**	*** detrimental effect on soil * suitable only for uncoloured and non-toxic streams * unacceptable to authorities**

Conclusions

The methods indicated for each process in Table A6-3 are those that have been found to be the most suitable for that particular effluent stream. It highlights the importance of segregation of the various streams in order to treat them individually. In general, effluents that are high in COD are most effectively treated by biological methods, either aerobic or anaerobic. There are a number of methods for removing colour from effluents, depending on the class of dye used, but the most effective over the range of dyes is oxidation methods (such as Fenton's Reagent) or membrane treatment using reverse osmosis. Effluents that are high in BOD and SS are best removed through coagulation and flocculation methods followed either by settling or dissolved air flotation. Those effluent streams containing alkaline (mercerizing and bleaching) can be treated by membranes (ultra filtration) or evaporation and reused in the same process. The same is true for synthetic sizes where they can be recycled after filtration.

As mentioned previously, there is no one single treatment technology that can effectively treat the final effluent from the textile industry and a combination of the available methods is necessary in order to achieve the required discharge standards.