Analysis of causes for high organic and inorganic pollution in denim processing effluent

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ABSTRACT

Textile industry is one of the most important and rapidly developing industrial sectors. It has a high importance in terms of its environmental impact, since it consumes considerably high amount of water and produces highly polluted discharge water in large amount. In this study, the pollution assessment was performed in various parts of denim processing textile wastewater in three steps. In the first step the wastewater samples were collected from the Denim processing industry. The pollution load was analysed in terms of Chemical Oxygen Demand (COD), pH, Conductivity, Total Dissolved Solid (TDS) as per standards. Higher Organic content in the Mercerizer effluent was identified which is due to the acidic nature of Neutralizing agents. As a second step, ANOVA and correlation coefficient analysis were performed to identify the significant differences, correlation between the properties of effluent respectively. In the final step the reductions in pollution load were achieved by applying suitable pollution prevention strategies.

Keywords: Textile wastewater, pH, conductivity, COD, TDS, Pollution prevention

1. Introduction

Amongst the top foreign exchange earning industries for India (Naik, 2001). The textile units are scattered all over India. The textile industry involves processing or converting raw material into finished cloth employing various operations. It consumes large quantities of water and produces polluted waste effluents (Karthikeyan et al, 1999). Water is used extensively throughout textile processing operations. Almost all dyes, specialty chemicals, and finishing chemicals are applied to textile substrates from water baths. In addition, most fabric preparation steps, including desizing, scouring, bleaching, and mercerizing, use aqueous systems. The amount of water used varies widely in the industry, depending on the specific processes operated at the mill, the equipment used. Typically 0.2–0.5 m³ of water are needed to produce 1 kg of finished product (Marcucci et al, 2001).

Reducing water consumption in textile processing is important aspect of pollution prevention efforts; the excess water uses dilutes pollutants and add to the effluent load. Interest in ecologically friendly, wet-processing textile techniques has increased in recent years because of increased awareness of environmental issues throughout the world. Consumers in developed countries are demanding biodegradable and ecologically friendly textiles (Chavan, 2001)
Due to the high water consumption in the textile industry it is essential to study its reuse. Many processes have been studied to treat textile wastewaters (Balcioglu, 2001; Kent, 1974). Because of the hazards associated with the large amounts of textile wastewater, several studies were conducted worldwide resulting in a number of treatment techniques for this wastewater. The complexity of these techniques depends, to a large extent, on the intended fate of the treated water and the environmental laws of the country in which it exists (Vandevivere et al, 1998; Tunay, et al, 1996; Slokar et al, 1998; Rott et al, 1999). The main challenge for the textile industry today is to modify production methods, so they are more ecologically friendly at a competitive price, by using safer dyes and chemicals and by reducing cost of effluent treatment/disposal. Recycling has become a necessary element, not because of the shortage of any item, but because of the need to control pollution (Ramesh Babu et al, 2007). Textiles generally go through three or four stages of production that may include yarn formation, fabric formation, wet processing, and textile fabrication.

This study was carried out in the finishing department of denim processing machines like Mercerizer, Desizer and Finishing machines. From the each machine the effluents were collected in all its outlets then those effluents were analyzed to identify the amount of pollutants produced each part of the machine. In all the samples the pollutants were measured by Chemical Oxygen Demand, pH, Conductivity, Total Dissolved Solid method. The aim of this study is to identify the causes for high organic and inorganic load in the effluents, which are generated from the finishing department machines and chemicals. Further from this experimental study the reason for the causes of high pollution in each and every machine effluent were identified.

2. Materials and Method

The first step in a pollution prevention strategy for water is a thorough audit and characterization of wastewater from textile operations (Wood et al, 1992). In this study the effluent were collected to identify the pollution level in the each finishing machine. The most important parameters in wastewater from textile industry are COD (Chemical Oxygen Demand), BOD$_5$ (Biological Oxygen Demand), pH, fats, oil, nitrogen, phosphorus, sulphate, Dissolved solids and SS (Suspended Solids) (Tufekci et al, 1998), all these parameters were analyzed in this study. The test result values are average of at least 10 samples per machine and taken at arbitrary times.

2.1 Desizing

After the fabric (Denim) formation different feels were imported to the fabric by pre treatments and by adding different finishes. The presence of sizing ingredients in the fabric hinders processes, such as dyeing, printing, and finishing. For example, the presence of starch can hinder the penetration of the dye into the fiber, which necessitates removal of starch prior to dyeing or printing (Batra et al, 1985). Before the finishing process the desizing process were carried out to develop the proper penetration of the finishing chemicals.

The line diagram of Desizer is shown in Figure 1. In Desizer the effluent from the Closed Washer Tank (CWT) 1 - 4 and Open Tank chemicals where drained down the common outlet, which was piped to Effluent Treatment Plant (ETP). During this study the effluent were collected in its each outlet separately as shown in Figure 1.
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2.2 Mercerizer

The line diagram of the continuous mercerizing machine was given in Figure 2. The samples were collected from each outlet as shown in Figure 2. The effluent from steamer and open tank contain high percentage of caustic, so these effluents were directly taken to caustic recovery plant (CRP), other effluents are directly passed to effluent treatment plant as in Figure 2.

2.3 Finishing machines

In finishing department there are three different machines are available with different make. By using these machinery there are different kind of finishing are applied to the fabric like Flat (Desize-Mercerization-Finishing), Semi flat (Mercerization - Finishing), Normal (Singing - Finishing), Resin finish etc. Depending upon the finish the recipe and chemicals will alter. From these machineries the sample were collected from its final drain point.

2.4 Pollution testing methods

The collected sample from finishing department was taken to the testing laboratory and the analysis was made to identify the pollution level of each machine. Wastewater samples of each outlet of each machine were taken and analyzed for Chemical oxygen demand (COD), Total dissolved solids (TDS), pH and Conductivity levels. All the analyses were performed according to Standard Methods for the Examination of Water and Wastewater\textsuperscript{15}. The methods and procedure were discussed below.
2.5 pH measurement

The homogeneously mixed final sample was collected for testing of pH. The pH was measured using a Fisher, Accumet pH meter, model 610A. The pH meter was calibrated with pH 7 and pH 4 buffers before the pH of samples was measured according to Standard Methods for the Examination of Water and Wastewater (Lenore et al, 1996).

2.6 Total Dissolved Solid Measurement

Total dissolved solids (TDS) were measured by evaporation drying method according to Section C of Standard Methods for the Examination of Water and Wastewater. A measured amount of sample was pipetted onto a glass microfiber filter with a pore size 1.5 μm and dried at 103°C for 1 hour. Before weighing, the samples were placed in a desiccator and allowed to cool for 10-15 min.

2.8 Conductivity Measurement

The homogeneously mixed final sample was collected for testing of conductivity. The conductivity was measured using a Deluxe pH meter, model no 100. The conductivity meter was calibrated with different conductivity level with standard solution before the Conductivity of samples was measured according to Standard Methods for the Examination of Water and Wastewater (Lenore et al, 1996).

2.9 Chemical Oxygen demand (COD) measurement

The COD of the samples was determined after making proper dilutions. The closed reflux, titrimetric method was used. The digestion period was two hours. A description of the method can be found in Standard Methods for the Examination of Water and Wastewater (Lenore et al, 1996) and also in United States Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes (United States Environmental Protection Agency, 1979).

2.10 Statistical analysis

To identify the significance between pollution levels in difference operation of the machine the statistical analysis were performed using ANOVA (Analysis of variance). Further to confirm the differences, the Tukey HSD Test and Tukey B Tests were performed.

The correlation between variables was achieved by correlation coefficient value.

3. Result and discussion

During this study the effluents were collected from the each outlet of the machine and the detailed experimental work on the pollutant values like pH, Conductivity, COD and TDS were conducted and discussed as follows.

3.1. Desizer

The tests were carried out to identify the pollutants values at each outlet point of the machine. The results were analyzed as follows.
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Figure 3 represents the pH value range of the Desizer effluent. According to the Desizer the pH range is under control as per the standards (7.5 to 8.5) (Notification the Ministry of Science, 1996). Figure 4 represents the conductivity values of the effluent.

Figure 5 represents the TDS values of the effluent. These values reduced step by step from (Closed Washer Tank) CWT 1 to CWT 4. But it is high in open tank, and then there is a tremendous decrease from Open tank to CWT 1. Figure 6 represents the COD values of Desizer effluent. The graph shown that, there is a low COD values in CWT 1 to CWT 4 compared to open tank. It is observed that there is a great amount of high COD value at open tank.

3.1.1 Testing of chemicals

To conform this effect of open tank chemical in the value of TDS and COD, the both the test where conducted for the chemicals which are used in the Desizer. There are four chemical used in the machine. They are α Amylase Enzyme (I), Nonionic emulsifying agent, Nonionic Wetting agents and washing solution. The COD and TDS tests were carried for all the chemicals and the results were shown in Table 1.

From this test results, it is realized that the Nonionic Wetting Agent having high pollution load than any other chemicals used in desizing operation. Further by considering the high
usage of Nonionic Wetting Agent, it is identified as the main reason for the both COD and TDS values in the Desizer effluent. Further Nonionic emulsifying Agent plays the secondary role in generation of COD.

**Table 1: COD and TDS value of open tank chemicals**

<table>
<thead>
<tr>
<th>Sample (At available concentration)</th>
<th>TDS in mg/l</th>
<th>COD in mg/l</th>
<th>Usage in Kg (Total consumption for a month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonionic emulsifying Agent</td>
<td>200000</td>
<td>1464000</td>
<td>951</td>
</tr>
<tr>
<td>Nonionic Wetting Agent</td>
<td>900000</td>
<td>1720000</td>
<td>970</td>
</tr>
<tr>
<td>Washing Improving agent</td>
<td>600</td>
<td>15200</td>
<td>317</td>
</tr>
<tr>
<td>α Amylase Enzyme</td>
<td>417300</td>
<td>468000</td>
<td>1536</td>
</tr>
</tbody>
</table>

3.1.2 Application of Pollution Reduction Strategies

3.1.2.1 Substitution of low pollution load chemicals

In desizing Nonionic wetting agents and Nonionic emulsifying agent are used together, which increases the pollution load in final desizing effluent. Instead of that another one wetting agent was suggested from different manufacturer with low pollution level. The study results was shown below

**Figure 7: Wetting agent COD and TDS level**

Further the α Amylase Enzyme (I) which currently in use was suggested to replace with another α Amylase Enzyme (II) with different manufacturer, which having low TDS and COD value. Figure 8 shows the pollution values.
3.2 Mercerizer

The tests were carried out to identify the pollutants values at each outlet point of the mercer machine. The results were analyzed as follows.

**Figure 8:** Enzymes for Desizing

**Figure 9:** PH value of effluent from Mercerizer

**Figure 10:** Conductivity of effluent from Mercerizer

**Figure 11:** TDS of effluent from Mercerizer

**Figure 12:** COD of effluent from Mercerizer
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Figure 9 represents the pH value range of the Mercer effluent. The effluent which obtained from the CWT 1 was high alkaline nature. The pH value around 11.8, but the value reduced step by step for the subsequent washes. At CWT 4 there is a great reduction of the pH value due to the addition of acid for neutralization purpose. Further this avoids indigo back staining on the fabric. Figure 10 represents the conductivity values of the effluent this value reduced step by step from CWT 1 to CWT 4. The reduction in TDS value ultimately takes care of conductivity. Figure 10 represents the TDS values of the effluent. These values reduced step by step from CWT 1 to CWT 4. This can be understood from the figure. Figure 12 represents the COD values of Mercer effluent. The graph shown that, there is a low COD values in CWT 1 to CWT 3. But it is observed that there is a great increase in the COD value at CWT 4.

3.2.1 Testing of chemicals

To conform the effect of chemical in the value of TDS and COD of final effluent, the both the test where conducted for the chemicals which are used in the Mercerizer. There are three chemical used in the machine. They are. Pure Caustic solution, Washing improving agent (Green pol), Neutralizing agent (Green Acid). The COD and TDS tests were carried for all the chemicals and the results were shown in Table 2.

Table 2: Mercer chemical Pollution level

<table>
<thead>
<tr>
<th>Sample (At available concentration)</th>
<th>TDS in mg/l</th>
<th>COD in mg/l</th>
<th>Usage in Kg (Total consumption for a month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutralizing agent</td>
<td>3400</td>
<td>43600</td>
<td>10300</td>
</tr>
<tr>
<td>Washing improving agent</td>
<td>600</td>
<td>15200</td>
<td>430</td>
</tr>
<tr>
<td>Caustic solution</td>
<td>755000</td>
<td>26800</td>
<td>118200</td>
</tr>
</tbody>
</table>

The experimental results were shown in Figure 7-10. From the test it is confirmed that the acidic nature of the neutralizing agent is the main causes for high COD value in the mercer effluent. Table 5 shows that Neutralizing agent has the high amount of chemical oxygen demand than any other chemical used in Mercerization. Further it is also identified from Table 5; the caustic solution is the main reason for high TDS in the output values.

3.3 Finishing Machines

The effluent from final effluent out let of the machine was collected from each finishing machine. Then the experiment was carried out to identify the pollution level of the effluent. It was shown in Figure 13. In finishing machine the most commonly used chemicals are Softener, wetting agents, neutralizing agent and fastness improver. The results of these chemicals are shown in Table 3.

From the Figure 13 the pH values for the finishing machine are in the range of 4.5 – 5.6. The conductivity values of the final drain effluent were around 12000. The TDS and COD values of the final effluent also noticed high then the standards (Notification the Ministry of Science, 1996). The experimental results were shown in Table 6. From the results it is identified that Nonionic wetting agent is the chemical which posses high COD and TDS value. Even though softener used large quantity than Nonionic wetting agent, the pollution load is low for softener. It is noted that Nonionic Wetting agent is the reason for the high pollution value in the finishing machine effluent.
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Figure 13: Pollution of effluent from finishing Machine

Table 3: Finishing machine chemical Pollution level

<table>
<thead>
<tr>
<th>Sample (At available concentration)</th>
<th>COD mg/l</th>
<th>TDS mg/l</th>
<th>USAGE IN KG (Total consumption for a month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softener</td>
<td>352000</td>
<td>210000</td>
<td>3441</td>
</tr>
<tr>
<td>Nonionic Wetting agent</td>
<td>1328000</td>
<td>900000</td>
<td>1286</td>
</tr>
<tr>
<td>Neutralizing agent</td>
<td>300000</td>
<td>75000</td>
<td>623</td>
</tr>
</tbody>
</table>

3.3.1 Application of Pollution Reduction Strategies

3.3.1.1 Recovery and reuse of material

Recovery of some of the valuable material from the effluent stream substantially reduces the pollution, especially COD load. This recovered materials can be reused for some process, this will also lead to cost saving.

Caustic Soda recovery

The caustic which are used in the Mercerization process was recovered from separate plant called Caustic Recovery Plant (CRP). This process reduces the pollution load in the effluent and also increases the Effluent Treatment Efficiency

3.3.1.2 Substitution of low pollution load chemicals

In Mercerizer Caustic causes high TDS and neutralizing agent cause high COD. To replace the existing neutralizing agent (I) the test were conducted with some other available neutralizing agent (II) (Acetic acid based) but it is identified that acetic acid has high pollution than that. Even though it is economic then green acid it is very marginal when compare with pollution load as in Figure 14.
3.3.2 Process changes

To reduce the organic load in the final effluent some specific process changes are recommended in particular machines.

1. In Mercerizer the acid is used for the neutralizing purpose. In washer tank 4 the pH value maintained around 2 (To maintain the final output fabric pH).

2. Higher the acidic nature causes high COD value so it is recommended to maintain in the range of 4-5. To identify this test were carried out at different pH level and the result was shown above. It conforms that the organic content increases in the effluent when the acidic nature developed in the effluent, which is represented in Figure 15.

3. Further the effluent from washer tank 1 (in case of Mercer) also having high caustic content which leads high TDS value in final effluent. To avoid this, the Effluent from washer tank 1 also recommended passing to CRP (Caustic Recovery Plant).
3.3.3 Waste segregation

The effluents from the different part of the industry are segregated based on its pollution load and the concentration. The effluents which are segregated are

1. Effluent from Dyeing Department
2. Effluent from Pre treatment like Desizing and Mercerizing
3. Effluent from finishing machines

3.3.3.1 Economy in water use

If lower quantities of water are used for processing, lesser quantities of effluent only would be generated. To avoid the excess usage of water the following procedures are followed.

1. Modulated water use depending upon the throughput material.
2. Reuse of treated and cooling waters where ever possible
3. Good maintenance practices of machines.
4. Use of automatic water controls where ever possible

3.4 Statistical result

From the ANOVA results it was identified that there is no significant different between the variables within the machine. Further the correlation value was obtained. The results were shown in Table 4 and 5.

**Table 4:** Correlation analysis between variables of different operation

<table>
<thead>
<tr>
<th>Machine</th>
<th>Variables</th>
<th>Equation</th>
<th>Correlation co-efficient &quot;r&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercerizer</td>
<td>pH Vs COD</td>
<td>13526-835.2X</td>
<td>-0.87</td>
</tr>
<tr>
<td></td>
<td>TDS Vs Conductivity</td>
<td>3.463X - 14820</td>
<td>0.98</td>
</tr>
<tr>
<td>Desizer</td>
<td>TDS Vs Conductivity</td>
<td>0.752x - 4670</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>COD Vs TDS</td>
<td>1.034x - 1119</td>
<td>0.86</td>
</tr>
<tr>
<td>Finishing</td>
<td>COD Vs TDS</td>
<td>2.26X-1148</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>pH Vs COD</td>
<td>124334-25225X</td>
<td>-0.98</td>
</tr>
</tbody>
</table>

**Table 5:** ANOVA results for pollutants

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>d.f.</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>4</td>
<td>134.7145</td>
<td>33.6786</td>
<td>2.0389</td>
<td>0.105</td>
</tr>
<tr>
<td>Within Groups</td>
<td>45</td>
<td>743.3172</td>
<td>16.5182</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>878.0317</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It shows that the pH and COD have negative correlation. In the same way the TDS Vs Conductivity and COD Vs TDS were performed. These results strengthen the experimental results directly. The results indicates that in case of pH vs COD, the decrease in the pH values (more the acidic nature) leads to the high COD values. It is noted from the Figure 9 and Figure 12. In Figure 9 at washer tank 4 the pH value is 3.99 at that time the COD value is
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around ten thousand, but in the same time at washer tank 3 the pH value is 10.81 at that place the COD value around 2800.

Where in the case TDS vs Conductivity, they are directly related. When the dissolved solid content increases the conductivity also increases (around 84%), this can be understand from Figure 10, 11 and 4, 5. as stated by statistical result. At TDS vs. COD the correlation is around 86%, the influence of dissolved solid also increases COD value.

4. Summary

In this study, the pollution level of denim processing industry was analysed using the effluents from the different machines. The result shows that the Nonionic Wetting agent is responsible for high COD and TDS value in effluent from Desizer, compared with other chemicals. Acid, which is used as neutralizing agents, causes high COD value and Caustic causes high TDS in the final effluent. Hence, it is suggested to maintain the water pH level around 4 to 5 at the closed washer tank 4 and to bypass the effluent from closed washer tank 1 to Caustic recovery, which reduces the pollution level in the mercer effluent. Commonly in all finishing machines, Nonionic wetting agent is identified as high polluted chemical than others, which causes high COD and TDS value in finishing effluent. ANOVA and correlation coefficient analysis confirms the inter-relationship between the various pollutants is significant.

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5. References


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