Wastewater of Textile Industry and Its Treatment Processes

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Abstract

In this study, the wastewater originating from textile industry and its treatment methods together with alternative treatment processes were examined and a general evaluation was performed by compiling previous studies in the literature. Because of increasing population and industrial developments, a huge amount of wastewater is discharged to the environment above the level that the nature can eliminate. One of the most important industrial activities in Turkey with its magnitude of economy and provided employment is the textile industry and wastewater including contaminants (COD, azo dyes, BOD, TSS) in different concentrations is discharged as a result of the activities in this industry. The excess negative properties of textile wastewater for the environment and the health of human beings show how important is to find a solution for this problem. In various stages of textile industry, a significant amount of water is consumed and this situation puts forth the necessity for regular control of textile wastewater into consideration. In order for textile wastewater not to impair the environment and the health of human beings, this water should be discharged to the environment after various treatment methods. The reason for using various treatment methods for textile wastewater is that there are various contaminant parameters (especially azo dyes) present in the wastewater. It's necessary to find the most suitable treatment method for textile wastewater that will minimize the production and investment costs of wastewater treatment plants. One of the most dangerous wastewaters that is discharged from textile industry is dyed wastewater. Since the colour load of dyed wastewater is high and its biological degradation is difficult, it's also difficult to treat it. Nowadays, the treatment of dyed wastewater is performed mostly by physical and chemical methods and nanotechnological textile membrane structures have started to be used for a more effective treatment.

Key Words: Textile Industry, Textile Wastewater, Treatment, Dyestuff

1. Introduction

Textile is one of the important sectors in Turkey and the leading sector which produces excessive waste (Gönüllü, 2004). In that branch of industry there are different production processes. Thus wastewater amount, pollutant types and concentrations show different datas (Ölmez et al., 2003).

In textile industry wastewater are changeable in terms of amount and composition. The first reason of pollutants in the wastewater is the natural impurity in fibres. The second is the chemical materials that are used in processes. A huge amount of dye, carriers, chrome and its derivations and sulphur are found in wastewater (Kestioğlu, 1992). Apart from that, considering technological differences in production process and the other different variations that can come out, there are alterations in factories which use the same fibers. Even if the the amount can differ, the characteristics of wastewater are usually similar in the factories that use the same fiber (Birgül, 2006).

The common characteristics of textile wastewater are high chemical oxygen need (KOI), high biological oxygen need (BOI), high temperature, high PH, solid materials, phenol, sulphure and the colours caused by different dyes (Demir et al., 2000).

Important pollutants in textile wastewater are especially the organics and then colour, toxic materials, inhibitor compounds, active substances, chlorine compounds (AOX), ph, salt and dying substances (Sandyha and Swaminathan, 2006).
In textile industry there appears 40-65 wastewater per one kg product (Manu and Chaudhari, 2002). In textile industry most of the wastewater that carries great importance with respect to the formation amount and the pollutants which it comprise, are caused by dying processes. The main characteristic parameter of the wastewater that appears at the end of the dying process is colour and the source of that decomposed and colloidal formed colour are the dying substances used in those processes (Ölmez et al., 2006).

Besides its complex forms textile wastewater creates problems due to their high volume. This industry which takes place in the first ranks on account of water consumption, is one of the industries that have become the subject of works of recycling wastewater for the purpose of saving water sources. The other problem about the textile industry is that it produces wastewater in different forms and volumes since this industry has many subdivisions. That situation makes so difficult to make generalization in selecting refining methods and makes it compulsory to handle every production factory as a different sample (Demiral, 2008).

Upon selecting parameters that form the basis for the control of textile industry wastewater, the factors which are shown below have been considered (Erol, 2007):

- The sources of pollutant parameters must be determined in respect of inspection
- Selected pollutant parameter must be characteristic for that wastewater
- The effects and damages on the environment of pollutant parameters must be determined.
- Pollutant parameters must be refinable with the advanced methods
- Selected pollutant parameters must be measured in definite sensitivity.

The parameters which are selected to form basis to control for textile industry are shown below, respectively

**Table 1.** The dispersion of pollutant materials in subcategories (Göknil et al., 1984).

<table>
<thead>
<tr>
<th>Subcategories</th>
<th>Polluting Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing fleece</td>
<td>$BOI_s$, TAM, KOI, Oil and grease, pH</td>
</tr>
<tr>
<td>Wool dressing</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>The processes with little water</td>
<td>$BOI_s$, TAM, KOI, pH</td>
</tr>
<tr>
<td>Tissue dressing</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>Knitted fabric dressing</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>Carpet dressing</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>Open fiber and yarn dressing</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>Nonwoven fabric production</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>Operating matted fabric</td>
<td>$BOI_s$, TAM, KOI, Phenol, Sulphur, pH</td>
</tr>
<tr>
<td>Cocoon operating and natural silk production</td>
<td>$BOI_s$, TAM, KOI, T.Cr, Phenol, Sulphur, pH</td>
</tr>
</tbody>
</table>

### 1.1. The classification of wastewater caused by textile industry

In general, textile wastewater can be classified in 3 classes according to KOI content and colour density; high, average and lower intense wastewater. High intense wastewater is dark coloured water which has KOI concentration over 1600mg/l and very low light permeability. Average intense wastewater contains 800-1600mg/l KOI whereas lower intense wastewater contains under 800mg/l KOI content. Considering density, the colour of wastewater changes showing parallelization to these three classifications. The degree of difficulty in refining the wastewater is related with the degree of
Relative pollution. In general, it can be said that most of the wastewater takes places in average or lower intense wastewater class (Lin and Peng, 1994). The average characteristics of these 3 wastewater are shown in Table 2.

### Table 2. The average characteristics of textile wastewaters (Lin and Peng, 1994).

<table>
<thead>
<tr>
<th>Type</th>
<th>BOI (mg/L)</th>
<th>KOI (mg/L)</th>
<th>pH</th>
<th>AKM (mg/L)</th>
<th>Temperature (°C)</th>
<th>Oil (mg/L)</th>
<th>Conductibility (µS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High strong</td>
<td>500</td>
<td>1500</td>
<td>10</td>
<td>250</td>
<td>28</td>
<td>50</td>
<td>2900</td>
</tr>
<tr>
<td>Middle strong</td>
<td>270</td>
<td>970</td>
<td>9</td>
<td>137</td>
<td>28</td>
<td>21</td>
<td>2500</td>
</tr>
<tr>
<td>Low strong</td>
<td>100</td>
<td>460</td>
<td>10</td>
<td>91</td>
<td>31</td>
<td>10</td>
<td>2100</td>
</tr>
</tbody>
</table>

1.2. Dyeing wastewater caused by textile industry

Due to the dyeing substance in the content, the textile industry wastewater is quite coloured water than those of the other industries. Some values related to the characterization of wastewater in the dry-house in which different dyes and fibers are dyed are shown in Table 3.

### Table 3. The characterization of dying wastewater (Correira et al., 1994).

<table>
<thead>
<tr>
<th>Type of dye</th>
<th>Fiber variety</th>
<th>Colour (ADMI)</th>
<th>BOI (mg/L)</th>
<th>TOK (mg/L)</th>
<th>AKM (mg/L)</th>
<th>ÇKM (mg/L)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Polyamide</td>
<td>4000</td>
<td>240</td>
<td>315</td>
<td>14</td>
<td>2028</td>
<td>5,1</td>
</tr>
<tr>
<td>1:2 Metal complex</td>
<td>Polyamide</td>
<td>370</td>
<td>570</td>
<td>400</td>
<td>5</td>
<td>3945</td>
<td>6,8</td>
</tr>
<tr>
<td>Alkaline</td>
<td>Acrylic</td>
<td>5600</td>
<td>210</td>
<td>255</td>
<td>13</td>
<td>1469</td>
<td>4,5</td>
</tr>
<tr>
<td>Direct</td>
<td>Viscose</td>
<td>12500</td>
<td>15</td>
<td>140</td>
<td>26</td>
<td>2669</td>
<td>6,6</td>
</tr>
<tr>
<td>Reagent, non-continuous</td>
<td>Cotton</td>
<td>3890</td>
<td>0</td>
<td>150</td>
<td>32</td>
<td>12500</td>
<td>11,2</td>
</tr>
<tr>
<td>Reagent, continuous</td>
<td>Cotton</td>
<td>1390</td>
<td>102</td>
<td>230</td>
<td>9</td>
<td>691</td>
<td>9,1</td>
</tr>
<tr>
<td>Vat</td>
<td>Cotton</td>
<td>1910</td>
<td>294</td>
<td>265</td>
<td>41</td>
<td>3945</td>
<td>11,8</td>
</tr>
<tr>
<td>Dispers, high temperature</td>
<td>Polyester</td>
<td>1245</td>
<td>198</td>
<td>360</td>
<td>76</td>
<td>1700</td>
<td>10,2</td>
</tr>
</tbody>
</table>

Modern textile dyes are supposed to have high degree chemical and photolytic stability in order to keep their forms and colours. For that reason the dyes are produced showing resistance to the sunshine, detergent, soap and water. These characteristics of the dyes affects the methods of cleaning water (Mahramanlioğlu and Arkan, 2002).

The wastewater given to the main water decreases the light permeability in the water environment and affects the photosynthetic activities negatively. Furthermore, with the accumulation of the dyeing substance in water environment, there comes out the danger of toxic and carcinogenic products (Kocaer and Kalkan, 2002). Giving coloured wastewater to the environment may cause great damages to the human body, functions of kidneys, reproductive system, liver, brain and nervous system (Özcan and Özcan, 2004).

In natural water masses there occurs aesthetic corruption due to the existence of colour and it hinders the permeability of oxygen. The decrease of the decomposed oxygen in water masses severely affects the life in water environment (Kaykioğlu and Debik, 2006). For that reason getting rid of dyes in wastewater is the basic environmental problem and it is vital because the dyes are visible even in the low consantration (Gomez et al., 2007).

Dyeing wastewater may contain toxic components and heavy metals caused by chemicals and dyeing substances. With this structure dying wastewater causes problems in refining facilities. These problems are swelling in the mud, continuousness in colour, excessiveness in ph, temperature and heavy metals.
and the changes in speed of hydraulic flow. Also removing wastewater with biological methods cannot be provided since many kinds of dyes have been developed showing resistance to biological decomposition. Thus removing colour has become the most important environmental problem that can be faced in the matter of wastewater (Buckley, 1992).

2. The Refining Methods of the Textile Industry Wastewater

The textile industry wastewater is the wastewater which contains BOI, KOI, AKM and dyeing substance in high level (Mckay, 1984). That great amount of KOI and dyeing substance deteriorates the wastewater aesthetically, decreases the amount of decomposed oxygen which is vital for normal life and it makes difficult to refine wastewater (Asfour et al., 1985).

There are traditional methods which are formed by the pyhical, chemical and biological methods for refining the textile industry wastewater (Abo et al., 1988).

Koagulation and flocculation: Koagulation-flocculation refining methods are generally used in order to eliminate organic materials. Koagulant materials are usually effective on dyeing substance which are not decomposed. They have effects on decomposed dyeing substance. The disadvantages of the system are excessive cost, excessive mud and cost for removing that mud (Gaehr et al., 1994).

The refining textile wastewater with chemical methods has become the most used refining method. The most important reason of this is that the changes in wastewater quality can be tolerated by making changes in chemicals and the amount used (Socha, 1991).

Oxidation: Chemical oxidation process is based on the transference of the electrons among chemical samples. This process can also be called reduction and raising process. The aim of chemical oxidation is to transform a substance in the water into ambivalent or last product by being oxidized chemically. Oxidation implements like Chlorur, sodium hiphoroclit, ozone and hydrogen percosit have been used as an oxidant (Arıcı 2000; Copper 1995).

Chemical flocculation and sedimentation method: In this method flocculation and sedimentation are supplied with the help of chemicals. Flocculation which occurs with the help of chemical substances that are put into the wastewater removes the decomposed substances and colloids. The most used chemicals are Al2(SO4)3, FeCl3, FeSO4 and lime (Demiral, 2008).

Refining with cucurbituril: Cucurbituril is a polymer which is composed of glicoluril and formaldehit. Researches have shown that the compound has quite good sorption capacity for different kinds of textile dyes. Cucurbituril is known to form a complex with aromatic compounds and it is considered that this mechanism is valid for the absorbance of reactive dyes (Robinson et al., 2001).

Biological refining methods: In general KOI and BOI proportion of wastewater is between 3 and 4. That means that water can be biologically decomposed. It is assumed that 40-50% colour removal will occur because of the decomposition and it is stated that the dyes will be absorbed on flocculated mud. Also it is stated that removal of KOI can reach the value of 70% (Marmagne and Costa, 1996).

Most of the biological refining processes which are commonly used, are effective in removing KOI and turbidity whereas they are not effective in removing colour (Lin and Chen, 1997).

Keeping great amount of biomass in the anaerobic refining systems which are used for refining industrial wastewater provides good refining efficiency and also decrease in gas amount produced and water in better quality. One of the problems that can be faced during the working of these systems is that leaving of the biomass from the system and its sedimentation. In order to solve this problem on behalf of precipitating tanks membran anaerobic reactor system has been developed using opposite flow ultrafiltration system (Robinson et al., 2001).

2.1. Advanced refining methods

In refining dyes wastewater sufficient colour removing cannot be obtained by conventional biological refining methods, moreover physicochemical koagulation and flocculation methods are not effective too. Because of the variation in their chemical features, molecular size and structure of the dyes used in textile industry, biological refining methods cannot be effective in removing the colour. Apart from a
few methods dyes are not decomposed under the aerobic conditions, for example reactive dyes which causes dark coloured water leave the process without any alteration in their concentration (Erol, 2007).

**Fenton Reaktan:** In refining wastewater with fenton colour can be removed and also the organohalids which can be absorbed can be removed. Besides heavy metals which are caused by metal-complex kinds of dyes can be precipitated on the neutralization step with the ironoxide. Refining with fenton is more advantageous than the methods in which H₂O₂ is used (Sewekov, 1993).

The advantages and disadvantages of fenton are shown in Table 4.

**Table 4. The advantages and disadvantages of fenton (Arıcı, 2000).**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first investment cost is low</td>
<td>Additional chemical cost</td>
</tr>
<tr>
<td>Decrease in poison for biological refining</td>
<td>Removing mud cost</td>
</tr>
<tr>
<td>It can be used in different processes</td>
<td>The potential of polymerization reactions</td>
</tr>
<tr>
<td>Getting ineffective of toxic and resistant compounds</td>
<td>Continuing of normal chemical reactions</td>
</tr>
<tr>
<td>Sudden begining time</td>
<td>Potential corozion problems</td>
</tr>
<tr>
<td>Low hidrolic waiting period (1-2 hours)</td>
<td>Controlling foam</td>
</tr>
<tr>
<td>Chemical mud production</td>
<td>Special safety thoughts</td>
</tr>
</tbody>
</table>

**Electroliz:** In this method the forming of FeOH₂ and removing of acid dyes are carried out effectively. This process is occured by sorption on the precipitated iron or reduce the azo dyes into arilamins in Fe₂ environment. 80% of removing colour is provided in labrotary studies and the last process is used to the exit of water with cotton and polyester dyeing. The total of koagulation, electroliz and active mud systems are cheaper and has more effective KOI removing than the conventional methods (Erol, 2007).

**Photocatalysis:** Complete removing colour is not provided whereas totally 90% carbon removing is obtained (Erol, 2007).

**Ozone process:** It can be a good alternative to the other oxidation due to high potential of ozone oxidation furthermore it can rise most of the compounds to high level oxidation when the suitable environmental conditions are supplied. However there are organic materials that it gives very slow reactions or do not enter in reaction. Under these conditions for forming hidrocsil radical which is a strong oxidan oxidation processes have been developed such as UV/O₃, H₂O₂/O₃ and H₂O₂/UV-C (Arslan et al., 1999).

**Absorbtion:** Absorbtion step is used to remove organic substances which are biologically not decomposed. The most effective absorbtion substance is active carbon. The absorbtion of active carbon is one of the effective process in removing colour (Erol, 2007).

**Membrane Filtration:** Membrane Processes provides the recycling of waste water and alternative watersource (Demiral, 2008). Membrane system which is one of the physical methods is advanced refining method that is used removing dying substance from textile wastewater. This process provides advantages such as reuse of the wastewater and recycle of dying substance.

### 3. Previously Done Works About the Subject

At a work in 1996 Tünay and his co-workers tried chemical precipitation, chemical oxidation and absorbtion methods in wastewater which contains acid dye and analyzed the methods in respect of their removing colour efficacy. As a result in chemical precipidation experiments it is determined that...
removing colour has been provided from average level to the high level with their reasonable amount and it is shown that the most effective chemical is alumun.

In 2003 Alparslan analyzed the sample of wastewater used in textile industry and the performance of anerobik colon reactor and active mud sytem. Facultative PDF is used in order to smash the dyeing substance. Experimental studies have shown that unit of anecorobic which can even be worked low hidrolic keeping process provides great efforts to removing colour. It has also seen that anecorobic unit does not provide aid for KOI removing and decrease in time of ventilating the mud.

In 2003 Kapdan and his co-workers in their work analyzed the different hidrolic keeping process, initial KO2 concentration, and the effects of consantra tion of dyeing substance on colour and KO2 removing in Reactive Red 195 dye which has a widespread using area in textile industry in Turkey. In the experimental studies 300mg/l of initial KOI consantration and 100mg/l of consantration of dyeing substance and 85% of removing colour have been obtained in the 18 hours of waiting process. 15 % of removing colour has been observed in aerobic reactor and KOI removing efficiency has reached 90%.

In 2004 Öztekin analyzed the different keeping process, initial KO2 concentration and the effects of mud age and dyeing substance derişim on KO2 and removing colour in anecorobic-aerobic consecutive reaktor which works with sentetic wastewater which contains Remazol Rot RR dyeing substance. As a result even in the Do 500mg/l dying substance 90 % of removing colour is obtained. This result has shown that system can tolerate the high dying substance concentration.

In 2006 Birgül carried out refining studies operating advanced oxidation tecnicas to the exit water of wastewater refining facility of two different textile industry. To this end oxidation tecnicas which are composed of koagulation, fenton, like fenton and ozone processes have been operated on two different wastewater textile industry and each system is analyzed in respect of KOI and colour removing. When the refining methods are compared to each other according to removing datas it is seen that the fenton process is more suitable than the other methods for removing colour and KOI from textile wastewater.

In 2006 Vardar examined the subject of removing colour and KOI with electro chemical refining of a reactive dye bath that is used textile industry dyeing process. As a result although there occurs excessive amount of mud steel electrot and electrokoalugation are quiet active both in colour and organic substance. In spite of the fact that alimium electrot provides quite good organic substance removing it is observed that it is not successful in removing colour at determined optimum time.

In 2007 Gönülay studied on different catalysis types of basic dye solutions which are commonly used in textile industry and colour removing performance which will show in fotokatalic oxidation under lamp illumination which gives two different UV wavelenght (UV-C and UV-A).the effects of the parameters of selected Reactive Orange 16 dye resolution and catalysis consantration, initial dye consantration, PH and light intensity have been examined. As a result in the studies carried out with catalysis it has been observed that the efficiency of colour removing increases when the amount of catalysis increases and the efficiency of colour decreases when the dye consantration increases. Also the efficiency of colour removing increases with the increase of light intensity.

In 2007 Eren analyzed the stabile steps of the work which is supposed to be carried out in order to research the biological refining of sentetic wastewater which contains textile dyeing substance Remozal Brillant Violet 5R using impure microorganism in consecutive anecorobik/aerobic reactor. Colour and bactery consantration measurement results which is done in order to check the efficiency of system In the process of removing sentetic wastewater which contains impure microorganism and azo dye in consecutive anecorobic/aerobic reactor shows that colour removing occurs in anaerobic environment. It has been understood that aerobic environment does not make any sense in colour removing.

In 2008 Kırlaroğlu M. worked on electrokoalugation process which is one of the electrochemical refining methods in water and wastewater refining. On this work the comparison between alternative power source (ACPS) which increases the efficiency of refining by getting rid of catot pasivization but is expensive and the right flow power source(DCPS) has been made. The effect of alternative flow (AC) on system efficiency in removing dying substance with liquid resolution EC. As a result DC and AC experiments show similar results in optimum working parameters however using AC system is more advantageous in working cost, energy consumption, removing TOK and dye.
Başbuğ in 2008 examined dye absorption from textile wastewater and liquid resolution by using bentotit and ponza as an absorbent. Ponza and CDBA-ponza samples provide high colour removing in colon.

**Discussion**

The dyeing substance that are used in textile industry gives colour to the water. Coloured textile wastewater accumulates in water environment and deteriorates the aesthetic appearance of the water and decreases the light permeability. Decrease in the light permeability and the amount of decomposed oxygen causes the extinction of living beings and restricts the reuse of the water. Furthermore it is known that some dying substance contain toxic materials.

Not only the dyes but also wastewater caused by chemical materials cause vital problems. For this reasons refining the textile industry wastewater is very important.

The results obtained from the studies on textile industry wastewater are summarized below:

- Depending on the most suitable refining technology the parameters which forms the basis for discharge quality limits should be determined for the inspection of textile industry wastewater.

- Generally the textile wastewater is classified in 3 as high, average and lower intensity wastewater. The degree of difficulty in refining these wastewater is closely linked with relative pollution degree. In general most of the textile wastewater is in the class of lower or average intensity dirty wastewater.

- In order to decrease the initial investment and working cost of wastewater refining facility, the most suitable refining method should be determined. There are traditional methods which are composed of different compounds of biological, chemical and physical methods.

- According to the removing datas obtained from the comparison between refining alternatives It is stated that fenton process is more suitable method in removing K01 and colour from textile industry wastewater than the other advanced oxidation methods.

- Colour removing is not provided by biological refining but with chemical refining colour it has been observed that removing is happened effectively. However it is strictly stated that there aren’t colour parameters in discharge standards and limit values about it in our country.

- It has been seen that the colour removing is provided by anaerobic refining however it is not provided by aerobic refining.

- Membran process is a new technology which has found a wide using area in refining wastewater. By using this process especially the industries which discharge consantre waste supplies economical advantage and the amount of pollution will diminish in other areas (recycle etc.).

- It is observed that reverse osmose and nanofiltration membranes can be successfully used in refining textile wastewater.

- It is observed that the nanofiltration membrane stoppage is low and the efficiency of removing colour reaches almost 95%.

- As a consequence membrane technologies carries great potential in refining in the future. For that reason it is essential to begin to work in order to determine technological and economical advantage and usage area of unknown technologies in Turkey.

- Textile industry that takes places in the first ranks in water consumption have become mostly the subject of the studies and efforts on recycle and reuse of wastewater with the aim of saving watersources which are diminishing day by day.

- Turkey have to solve colour problems with advanced refining methods and reach the discharge criteria which European Union uses.

**References**

Alparslan, S., 2003: Color Removal from Textile Wastewater by Sequential Anaerobic-Aerobic Treatment System, Dokuz Eylul Universities, Yüksek Lisans Tezi, İzmir, 111s.


Başbuğ, M., 2008: Bentonit ve Ponza ile Sulu Çözeltiden ve Tekstil AtIsuyundan Boya Adsorpsiyonunun İncelenmesi, Süleyman Demirel Universities, Yüksek Lisans Tezi, Isparta.


Gönül, M.T., 2004: Endüstriyel Kirilenme Kontrolü Cilt1, Birsen Yayinevi, Kurtiş Matbaası, Kod no: Y. 0029, 466s, İstanbul.


Öztekin, R., 2004: Color Removal from Textile Wastewater in SBR., Dokuz Eylül Üniversitesi, Yüksek Lisans Tezi, İzmir, 136s.


