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# Textile Dyeing Wastewater Treatment

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## 1. Introduction

Textile industry can be classified into three categories viz., cotton, woolen, and synthetic fibers depending upon the used raw materials. The cotton textile industry is one of the oldest industries in China.

The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. Wastewater from printing and dyeing units is often rich in color, containing residues of reactive dyes and chemicals, such as complex components, many aerosols, high chroma, high COD and BOD concentration as well as much more hard-degradation materials. The toxic effects of dyestuffs and other organic compounds, as well as acidic and alkaline contaminants, from industrial establishments on the general public are widely accepted. At present, the dyes are mainly aromatic and heterocyclic compounds, with color-display groups and polar groups. The structure is more complicated and stable, resulting in greater difficulty to degrade the printing and dyeing wastewater (Shaolan Ding et al., 2010).

According to recent statistics, China's annual sewage has already reached 390 million tons, including 51% of industrial sewage, and it has been increasing with the rate of 1% every year. Each year about 70 billion tons of wastewater from textile and dyeing industry are produced and requires proper treatment before being released into the environment (State Environmental Protection Administration, 1994).

Therefore, understanding and developing effective printing-dye industrial wastewater treatment technology is environmentally important.

### 1.1 Textile printing and dyeing process

Textile Printing and dyeing processes include pretreatment, dyeing / printing, finishing and other technologies.

Pre-treatment includes desizing, scouring, washing, and other processes. Dyeing mainly aims at dissolving the dye in water, which will be transferred to the fabric to produce colored fabric under certain conditions. Printing is a branch of dyeing which generally is defined as 'localized dyeing' i.e. dyeing that is confined to a certain portion of the fabric that constitutes the design. It is really a form of dyeing in which the essential reactions involved are the same as those in dyeing. In dyeing, color is applied in the form of solutions, whereas color is applied in the form of a thick paste of the dye in printing. Both natural and synthetic textiles are subjected to a variety of finishing processes. This is done to improve specific properties in the finished fabric and involves the use of a large number of finishing agents for softening, cross-linking, and waterproofing. All of the finishing processes contribute to water pollution. In

addition, in different circumstances, the singeing, mercerized, base reduction, and other processes should have been done before dyeing/printing.

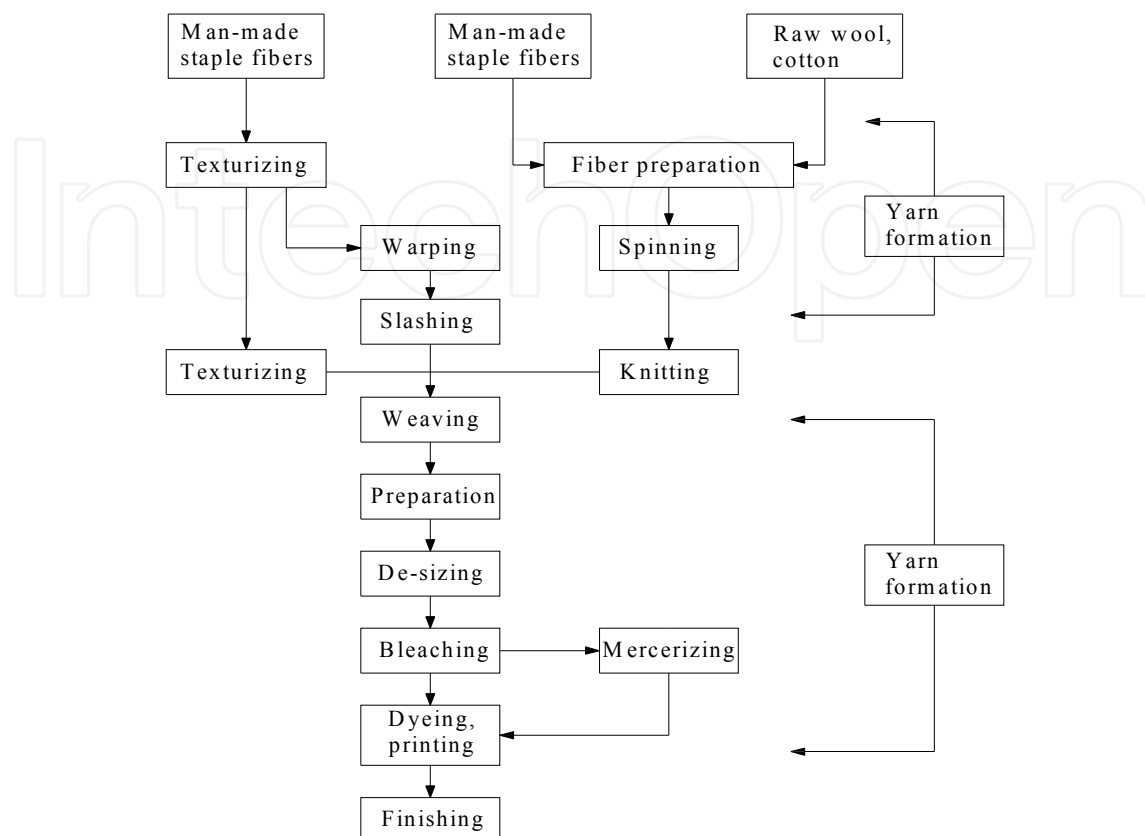


Fig. 1. Various steps involved in processing textile in a cotton mill (B. Ramesh Babu et al.,2007).

In the textile dyeing industry, bleaching is an important process. It has three technologies: sodium hypochlorite bleaching; hydrogen peroxide bleaching and sodium chlorite bleaching. Sodium hypochlorite bleaching and sodium chlorite bleaching are the most commonly used processes. Normal concentration of chlorine dioxide in bleaching effluent is 10-200 mg/L. As chlorine dioxide is a strong oxidant, it is very corrosive and toxic as well. The typical printing and dyeing process is shown in Fig. 1 and the main used fiber dyes at present have been shown in Table 1 (Kelu Yan,2005).

The variety of fiber	The commonly used dyes
Cellulose fiber	Direct dyes, Reactive dyes, Vat dyes, Sulfide dyes, Azo dyes
Wool	Acid dyes
Silk	Direct dyes, Acid dyes
Polyester	Azo dyes, Disperse dyes
Polyester-cotton	Disperse / Vat dyes, Disperse / Insoluble dye
polyacrylonitrile fiber	Cationic dyes, Disperse dyes
polyacrylonitrile fiber -wool	Cationic dyes, Acid dyes
vinylon	Direct dyes, Vat dyes, Sulfur dyes, Acid dyes,

Table 1. The varieties of common used fiber

## 1.2 Production of textile industry pollution

Textile Printing and dyeing processes include pre-treatment, dyeing and printing, finishing. The main pollutants are organic matters which come from the pre-treatment process of pulp, cotton gum, cellulose, hemicellulose and alkali, as well as additives and dyes using in dyeing and printing processes. Pre-treatment wastewater accounts for about 45% of the total, and dyeing/printing process wastewater accounts for about 50%~55%, while finishing process produces little.

In China, chemical fiber accounts for about 69% of total in which polyester fibers accounts for more than 80%. Cotton accounts for 80% of the natural fiber production. Therefore, the dyeing wastewater analysis of production and pollution is based on these two fibers.

Pre-treatment of cotton includes desizing and scouring. The main pollutants are the impurities in the cotton, cotton gum, hemicellulose and the slurry, alkali in weaving process. The current average COD concentration in the pre-treatment is 3000 mg/L. The main pollutants in dyeing/printing are auxiliaries and the residual dyes. The average concentration of COD is 1000 mg/L and the total average concentration is 2000 mg/L after mixing.

Pre-treatment of polyester fibers mainly involves in the reduction with alkali. The so-called reduction is treating the polyester fabric with 8% of sodium hydroxide at 90 °C for about 45 minutes. Some polyester fabrics will peel off and decompose into terephthalic acid and ethylene glycol so that a thin polyester fabric will have the feel of silk. This process can be divided into continuous and batch type. Taking the batch type as an example, the concentration of COD is up to 20000 mg/L-60000 mg/L. The wastewater from reduction process may account for only 5% of the volume of wastewater, while COD accounts for 60% or more in the conventional dyeing and finishing business.

The chroma is one pollutant of the wastewater which causes a lot of concerns. In the dyeing process, the average dyeing rate is more than 90%. It means that the residual dyeing rate in finishing wastewater is about 10%, which is the main reason of contamination. According to the different dyes and process, the chroma is 200 to 500 times higher than before.

pH is another factor of the dyeing wastewater. Before the printing and the dyeing process, pH is another factor, the pH of dyeing wastewater remains between 10 to 11 when treated by alkali at high temperature around 90°C in the process of desizing, scouring and mercerization. Polyester base reduction process mainly uses sodium hydroxide, and the total pH is also 10 to 11. Therefore, most dyeing water is alkaline and the first process is to adjust the pH value of the textile dyeing wastewater.

The total nitrogen and ammonia nitrogen come from dyes and raw materials, which is not very high, about 10 mg/L. But the urea is needed while using batik techniques. Its total nitrogen is 300 mg/L, which is hard to treat. The phosphorus in the wastewater comes from the phosphor detergents. Considering the serious eutrophication of surface water, it needs to be controlled. Some enterprises use trisodium phosphate so that the concentration of phosphorus will reach 10 mg/L. So, this phosphorus must be removed in the pre-treatment.

In the production process, suspended substance comes from fiber scrap and undissolved raw materials. It will be removed through the grille, grid, etc. The suspended solids (SS) in the outflow mainly come from the secondary sedimentation tank, whose sludge has not been separated completely which will reach 10-100 mg/L as usual.

Sulfide mainly comes from the sulfur, which is a kind of cheap and qualified dye. Due to its toxicity, it has been forbidden in developed countries. However, in China, some enterprises

are still using it, so it has been included in the wastewater standards. The sulfide in the wastewater is about 10 mg/L. There are two main sources of hexavalent chromium. Cylinder engraving makes the wastewater containing hexavalent chromium. However, this technology has not been used. Another possible source is the use of potassium dichromate additive in hair dyeing process. Aniline mainly comes from the dyes. The color of the dye comes from the chromophore. Some dyes have a benzene ring, amino, etc., which will be decomposed in the wastewater treatment process.

The potential specific pollutants from textile Printing and dyeing is shown in Table 2 (C. All'egre et al.,2006).

Process	Compounds
Desizing	Sizes, enzymes, starch, waxes, ammonia.
Scouring	Disinfectants and insecticides residues, NaOH, surfactants, soaps, fats, waxes, pectin, oils, sizes, anti-static agents, spent solvents, enzymes.
Bleaching	H <sub>2</sub> O <sub>2</sub> , AOX, sodium silicate or organic stabiliser, high pH.
Mercerizing	High pH, NaOH
Dyeing	Colour, metals, salts, surfactants, organic processing assistants, sulphide, acidity/alkalinity, formaldehyde.
Printing	Urea, solvents, colour, metals.
Finishing	Resins, waxes, chlorinated compounds, acetate, stearate, spent solvents, softeners.

Table 2. Specific pollutants from textile and dyeing processing operations

### 1.3 Textile dyeing wastewater risk

Discharged wastewater by some industries under uncontrolled and unsuitable conditions is causing significant environmental problems. The importance of the pollution control and treatment is undoubtedly the key factor in the human future. If a textile mill discharges the wastewater into the local environment without any treatment, it will have a serious impact on natural water bodies and land in the surrounding area. High values of COD and BOD<sub>5</sub>, presence of particulate matter and sediments, and oil and grease in the effluent causes depletion of dissolved oxygen, which has an adverse effect on the aquatic ecological system.

Effluent from textile mills also contains chromium, which has a cumulative effect, and higher possibilities for entering into the food chain. Due to usage of dyes and chemicals, effluents are dark in color, which increases the turbidity of water body. This in turn hampers the photosynthesis process, causing alteration in the habitat (Joseph Egli,2007).

### 1.4 The textile industry standards for water pollutants

As the wastewater is harmful to the environment and people, there are strict requirements for the emission of the wastewater. However, due to the difference in the raw materials, products, dyes, technology and equipment, the standards of the wastewater emission have too much items. It is developed by the national environmental protection department according to the local conditions and environmental protection requirements which is not fixed. It varies according to the situation in different regions. Therefore, the nature of emission targets is priorities of the points.

Serial number	Parameters	The Limits of Discharged Concentration	The Limits of Discharged Concentration for new Factory	The Special Limits of Discharged Concentration
1	COD	100mg/L	80 mg/L	60 mg/L
2	BOD	25 mg/L	20 mg/L	15 mg/L
3	pH	6~9	6~9	6~9
4	SS	70 mg/L	60 mg/L	20 mg/L
5	Chrominance	80	60	40
6	TN	20 mg/L	15 mg/L	12 mg/L
7	NH <sub>3</sub> -N	15 mg/L	12 mg/L	10 mg/L
8	TP	1.0 mg/L	0.5 mg/L	0.5 mg/L
9	S	1.0 mg/L	Can not be detected	Can not be detected
10	ClO <sub>2</sub>	0.5 mg/L	0.5 mg/L	0.5 mg/L
11	Cr <sup>6+</sup>	0.5 mg/L	Can not be detected	Can not be detected
12	Aniline	1.0 mg/L	Can not be detected	Can not be detected

Table 3. "Textile industry standards for water pollutants"

For printing and dyeing wastewater, the first consideration is the organic pollutants, color and heavy metal ions. Recently, as the lack of water, the recovery of wastewater should be considered. So the decolorization of the printing and dyeing wastewater increased heavily. The standards of printing and dyeing are different in different countries. Through access to the relevant information, the textile industry standards for water pollutants in China, Germany, U.S have been found.

#### 1.4.1 Textile industry standards for water pollutants in China

For the emission standards of the textile dyeing wastewater in China, it is the very stringent standards in the world. The emission standards for different indicators in textile industry standards for water pollutants in China have been shown in table 3 ("Discharge standard of water pollutants for dyeing and finishing of textile industry").

#### 1.4.2 Textile industry standards for water pollutants in Germany

The emission standards for different indicators in textile industry standards for water pollutants in Germany have been shown in table 4 ("Discharge standard of water pollutants for dyeing and finishing of textile industry").

Serial number	Parameters	The Limits of Discharged Concentration
1	COD	160mg/L
2	BOD	25 mg/L
3	TP	2.0 mg/L
4	TN	20 mg/L
5	NH <sub>3</sub> -N	10 mg/L
6	Nitrite	1.0 mg/L

Table 4. Textile industry standards for water pollutants



The requirements of ammonia and total nitrogen are adjusted for the biochemical outflow at 12°C or above. Besides, the standard has also made the following emission requirements for the wastewater at the production stain.

There must not be in the wastewater:

1. Organic chlorine carriers (dyed acceleration)
2. Separation of chlorine bleach materials, except the sodium chlorite from the bleached synthetic fibers
3. The free chlorine after using sodium chlorite
4. Arsenic, mercury and their mixtures
5. Alkyl phenol as a bleaching agent (APEO)
6. Cr<sup>6+</sup> compounds in the oxidizing of sulfur dyes and vat dyes
7. EDTA, DTPA, and phosphate in the water treatment softeners
8. Accumulation of chemicals, dyes and textile auxiliaries

### 1.4.3 Textile industry standards for water pollutants in U.S.

#### Printing and dyeing wastewater

It is the order for the printing and dyeing, including rinsing, dyeing, bleaching, washing, drying and other similar processes.

The requirements using BPT (best practical control tech.) which is published by EPA has shown in Table 5 ("Discharge standard of water pollutants for dyeing and finishing of textile industry").

#### Fabric printing and dyeing wastewater

It is adjusted for the fabric printing and dyeing wastewater, including bleaching, mercerization, dyeing, resin processing, washing, drying and so on.

The requirements using BPT (best practical control tech.) to treat the fabric printing and dyeing wastewater has been shown in Table 6 ("Discharge standard of water pollutants for dyeing and finishing of textile industry").

Serial number	Parameters	BPT	
		Maximum	Average of 30 days
		Kg/t(Fabric)	
1	BOD <sub>5</sub>	22.4	11.2
2	COD	163.0	81.5
3	TSS	35.2	17.6
4	S	0.28	0.14
5	Phenol	0.14	0.07
6	Cr	0.14	0.07
7	pH	6.0~9.0	6.0~9.0

Table 5. Emission standards for gross printing and dyeing wastewater

#### Yarn printing and dyeing wastewater

It is adjusted for the Yarn printing and dyeing wastewater, including washing, mercerization, resin processing, dyeing and special finishing.

The requirements using BPT (best practical control tech.) to treat the yarn printing and dyeing wastewater has been shown in Table 7 ("Discharge standard of water pollutants for dyeing and finishing of textile industry").

Serial number	Parameters	BPT	
		Maximum	Average of 30 days
		Kg/t(Fabric)	
1	BOD <sub>5</sub>	5.0	2.5
2	COD	60	30
3	TSS	21.8	10.9
4	S	0.20	0.10
5	Phenol	0.10	0.05
6	Cr	0.10	0.05
7	pH	6.0~9.0	6.0~9.0

Table 6. Emission standards for fabric printing and dyeing wastewater

Serial number	Parameters	BPT	
		Maximum	Average of 30 days
		Kg/t(Fabric)	
1	BOD <sub>5</sub>	6.8	3.4
2	COD	84.6	42.3
3	TSS	17.4	8.7
4	S	0.24	0.12
5	Phenol	0.12	0.06
6	Cr	0.12	0.06
7	pH	6.0~9.0	6.0~9.0

Table 7. Emission standards for yarn printing and dyeing wastewater

## 2. Textile dyeing wastewater treatment processes

The textile dyeing wastewater has a large amount of complex components with high concentrations of organic, high-color and changing greatly characteristics. Owing to their high BOD/COD, their coloration and their salt load, the wastewater resulting from dyeing cotton with reactive dyes are seriously polluted. As aquatic organisms need light in order to develop, any deficit in this respect caused by colored water leads to an imbalance of the ecosystem. Moreover, the water of rivers that are used for drinking water must not be colored, as otherwise the treatment costs will be increased. Obviously, when legal limits exist (not in all the countries) these should be taken as justification. Studies concerning the feasibility of treating dyeing wastewater are very important (C. All'egre et al.,2006).

In the past several decades, many techniques have been developed to find an economic and efficient way to treat the textile dyeing wastewater, including physicochemical, biochemical, combined treatment processes and other technologies. These technologies are usually highly efficient for the textile dyeing wastewater.



## 2.1 Physicochemical wastewater treatment

Wastewater treatment is a mixture of unit processes, some physical, others chemical or biological in their action. A conventional treatment process is comprised of a series of individual unit processes, with the output (or effluent) of one process becoming the input (influent) of the next process. The first stage will usually be made up of physical processes. Physicochemical wastewater treatment has been widely used in the sewage treatment plant which has a high removal of chroma and suspended substances, while it has a low removal of COD. The common physicochemical methods are shown as followed.

### 2.1.1 Equalization and homogenization

Because of water quality highly polluted and quantity fluctuations, complex components, textile dyeing wastewater is generally required pretreatment to ensure the treatment effect and stable operation.

In general, the regulating tank is set to treat the wastewater. Meantime, to prevent the lint, cotton seed shell, and the slurry settle to the bottom of the tank, it's usually mixed the wastewater with air or mechanical mixing equipment in the tank. The hydraulic retention time is generally about 8 h.

### 2.1.2 Floatation

The floatation produces a large number of micro-bubbles in order to form the three-phase substances of water, gas, and solid. Dissolved air under pressure may be added to cause the formation of tiny bubbles which will attach to particles. Under the effect of interfacial tension, buoyancy of bubble rising, hydrostatic pressure and variety of other forces, the microbubble adheres to the tiny fibers. Due to its low density, the mixtures float to the surface so that the oil particles are separated from the water. So, this method can effectively remove the fibers in wastewater.

### 2.1.3 Coagulation flocculation sedimentation

Coagulation flocculation sedimentation is one of the most used methods, especially in the conventional treatment process.

Active on suspended matter, colloidal type of very small size, their electrical charge give repulsion and prevent their aggregation. Adding in water electrolytic products such as aluminum sulphate, ferric sulphate, ferric chloride, giving hydrolysable metallic ions or organic hydrolysable polymers (polyelectrolyte) can eliminate the surface electrical charges of the colloids. This effect is named coagulation. Normally the colloids bring negative charges, so the coagulants are usually inorganic or organic cationic coagulants (with positive charge in water).

The metallic hydroxides and the organic polymers, besides giving the coagulation, can help the particle aggregation into flocks, thereby increasing the sedimentation. The combined action of coagulation, flocculation and settling is named clariflocculation.

Settling needs stillness and flow velocity, so these three processes need different reactions tanks. This processes use mechanical separation among heterogeneous matters, while the dissolved matter is not well removed (clariflocculation can eliminate a part of it by absorption into the flocks). The dissolved matter can be better removed by biological or by other physical chemical processes (Sheng.H et al.,1997).

But additional chemical load on the effluent (which normally increases salt concentration) increases the sludge production and leads to the uncompleted dye removal.

### 2.1.4 Chemical oxidation

Chemical operations, as the name suggests, are those in which strictly chemical reactions occur, such as precipitation. Chemical treatment relies upon the chemical interactions of the contaminants we wish to remove from water, and the application of chemicals that either aid in the separation of contaminants from water, or assist in the destruction or neutralization of harmful effects associated with contaminants. Chemical treatment methods are applied both as stand-alone technologies and as an integral part of the treatment process with physical methods (K.Ranganathan et al.,2007).Chemical operations can oxidize the pigment in the printing and dyeing wastewater as well as bleaching the effluent. Currently, Fenton oxidation and ozone oxidation are often used in the wastewater treatment.

#### 2.1.4.1 Fenton reaction

Oxidative processes represent a widely used chemical method for the treatment of textile effluent, where decolourisation is the main concern. Among the oxidizing agents, the main chemical is hydrogen peroxide ( $H_2O_2$ ), variously activated to form hydroxyl radicals, which are among the strongest existing oxidizing agents and are able to decolourise a wide range of dyes.

A first method to activate hydroxyl radical formation from  $H_2O_2$  is the so called Fenton reaction, where hydrogen peroxide is added to an acidic solution (pH=2-3) containing  $Fe^{2+}$  ions.

Fenton reaction is mainly used as a pre-treatment for wastewater resistant to biological treatment or/and toxic to biomass. The reaction is exothermic and should take place at temperature higher than ambient. In large scale plants, however, the reaction is commonly carried out at ambient temperature using a large excess of iron as well as hydrogen peroxide. In such conditions ions do not act as catalyst and the great amount of total COD removed has to be mainly ascribed to the  $Fe(OH)_3$  co-precipitation. The main drawbacks of the method are the significant addition of acid and alkali to reach the required pH, the necessity to abate the residual iron concentration, too high for discharge in final effluent, and the related high sludge production (Sheng.H et al.,1997).

#### 2.1.4.2 Ozone oxidation

It is a very effective and fast decolourising treatment, which can easily break the double bonds present in most of the dyes. Ozonation can also inhibit or destroy the foaming properties of residual surfactants and it can oxidize a significant portion of COD.

Moreover, it can improve the biodegradability of those effluents which contain a high fraction of nonbiodegradable and toxic components through the conversion (by a limited oxidation) of recalcitrant pollutants into more easily biodegradable intermediates. As a further advantage, the treatment does increase neither the volume of wastewater nor the sludge mass.

Full scale applications are growing in number, mainly as final polishing treatment, generally requiring up-stream treatments such as at least filtration to reduce the suspended solids contents and improve the efficiency of decolourisation. Sodium hypochlorite has been widely used in the past as oxidizing agent. In textile effluent it initiates and accelerates azo bond cleavage. The negative effect is the release of carcinogenic aromatic amines and otherwise toxic molecules and, therefore, it should not be used (Sheng.H et al.,1997).

### 2.1.5 Adsorption

Adsorption is the most used method in physicochemical wastewater treatment, which can mix the wastewater and the porous material powder or granules, such as activated carbon and clay, or let the wastewater through its filter bed composed of granular materials.

Through this method, pollutants in the wastewater are adsorbed and removed on the surface of the porous material or filter.

Commonly used adsorbents are activated carbon, silicon polymers and kaolin. Different adsorbents have selective adsorption of dyes. But, so far, activated carbon is still the best adsorbent of dye wastewater. The chroma can be removed 92.17% and COD can be reduced 91.15% in series adsorption reactors, which meet the wastewater standard in the textile industry and can be reused as the washing water. Because activated carbon has selection to adsorb dyes, it can effectively remove the water-soluble dyes in wastewater, such as reactive dyes, basic dyes and azo dyes, but it can't adsorb the suspended solids and insoluble dyes. Moreover, the activated carbon can not be directly used in the original textile dyeing wastewater treatment, while generally used in lower concentration of dye wastewater treatment or advanced treatment because of the high cost of regeneration.

### **2.1.6 Membrane separation process**

Membrane separation process is the method that uses the membrane's micropores to filter and makes use of membrane's selective permeability to separate certain substances in wastewater. Currently, the membrane separation process is often used for treatment of dyeing wastewater mainly based on membrane pressure, such as reverse osmosis, ultrafiltration, nanofiltration and microfiltration. Membrane separation process is a new separation technology, with high separation efficiency, low energy consumption, easy operation, no pollution and so on. However, this technology is still not large-scale promoted because it has the limitation of requiring special equipment, and having high investment and the membrane fouling and so on (K.Ranganathan et al.,2007) .

#### **2.1.6.1 Reverse osmosis**

Reverse osmosis membranes have a retention rate of 90% or more for most types of ionic compounds and produce a high quality of permeate. Decolorization and elimination of chemical auxiliaries in dye house wastewater can be carried out in a single step by reverse osmosis. Reverse osmosis permits the removal of all mineral salts, hydrolyzed reactive dyes, and chemical auxiliaries. It must be noted that higher the concentration of dissolved salt, the more important the osmotic pressure becomes; therefore, the greater the energy required for the separation process (B. Ramesh Babu et al.,2007) .

#### **2.1.6.2 Nanofiltration**

Nanofiltration has been applied for the treatment of colored effluents from the textile industry. Its aperture is only about several nanometers, the retention molecular weight by which is about 80-1000da, A combination of adsorption and nanofiltration can be adopted for the treatment of textile dye effluents. The adsorption step precedes nanofiltration, because this sequence decreases concentration polarization during the filtration process, which increases the process output. Nanofiltration membranes retain low molecular weight organic compounds, divalent ions, large monovalent ions, hydrolyzed reactive dyes, and dyeing auxiliaries. Harmful effects of high concentrations of dye and salts in dye house effluents have frequently been reported. In most published studies concerning dye house effluents, the concentration of mineral salts does not exceed 20 g/L, and the concentration of dyestuff does not exceed 1.5 g/L. Generally, the effluents are reconstituted with only one dye, and the volume studied is also low. The treatment of dyeing wastewater by nanofiltration represents one of the rare applications possible for the treatment of solutions with highly concentrated and complex solutions (B. Ramesh Babu et al.,2007).

A major problem is the accumulation of dissolved solids, which makes discharging the treated effluents into water streams impossible. Various research groups have tried to develop economically feasible technologies for effective treatment of dye effluents. Nanofiltration treatment as an alternative has been found to be fairly satisfactory. The technique is also favorable in terms of environmental regulating.

### 2.1.6.3 Ultrafiltration

Ultrafiltration whose aperture is only about 1nm-0.05  $\mu$ m, enables elimination of macromolecules and particles, but the elimination of polluting substances, such as dyes, is never complete. Even in the best of cases, the quality of the treated wastewater does not permit its reuse for sensitive processes, such as dyeing of textile. So the retention molecular weight is range from 1000-300000da. Rott and Minke (1999) emphasize that 40% of the water treated by ultrafiltration can be recycled to feed processes termed "minor" in the textile industry (rinsing, washing) in which salinity is not a problem. Ultrafiltration can only be used as a pretreatment for reverse osmosis or in combination with a biological reactor (B. Ramesh Babu et al.,2007).

### 2.1.6.4 Microfiltration

Microfiltration whose aperture is about 0.1-1  $\mu$ m is suitable for treating dye baths containing pigment dyes, as well as for subsequent rinsing baths. The chemicals used in dye bath, which are not filtered by microfiltration, will remain in the bath. Microfiltration can also be used as a pretreatment for nanofiltration or reverse osmosis (B. Ramesh Babu et al.,2007).

Textile wastewater contains large amounts of difficult biodegradable organic matter and inorganic. At present, many factories have adopted physicochemical treatment process. Some typical physicochemical treatment process is shown in Table 8 and Fig. 2 (Kangmei Zeng et al.,2005).

## 2.2 Biological wastewater treatment method

The biological process removes dissolved matter in a way similar to the self depuration but in a further and more efficient way than clariflocculation. The removal efficiency depends upon the ratio between organic load and the bio mass present in the oxidation tank, its temperature, and oxygen concentration.

The bio mass concentration can increase, by aeration the suspension effect but it is important not to reach a mixing energy that can destroy the flocks, because it can inhibit the following settling.

Normally, the biomass concentration ranges between 2500-4500 mg/l, oxygen about 2 mg/l. With aeration time till 24 hours the oxygen demand can be reduced till 99%.

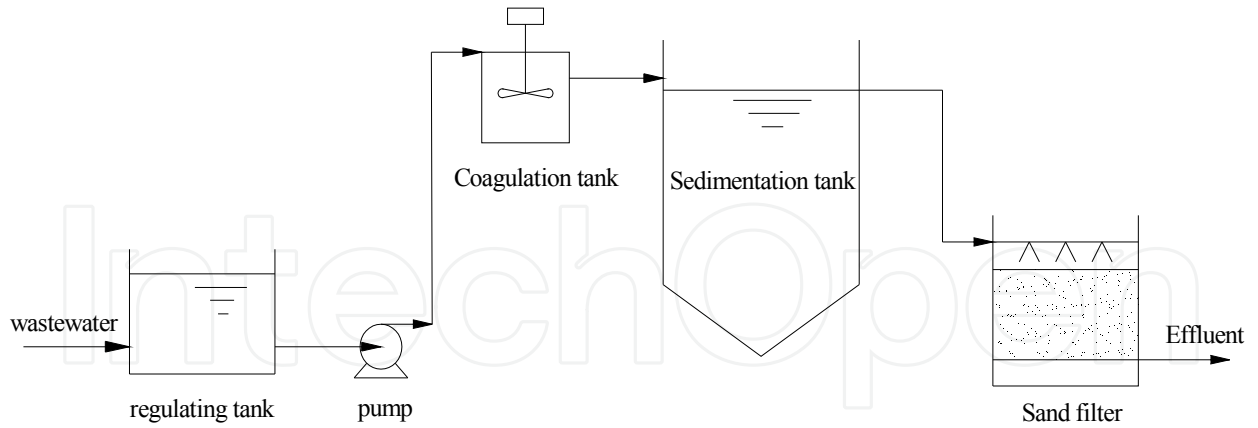
According to the different oxygen demand, biological treatment methods can be divided into aerobic and anaerobic treatment. Because of high efficiency and wide application of the aerobic biological treatment, it naturally becomes the mainstream of biological treatment.

### 2.2.1 Aerobic biological treatment

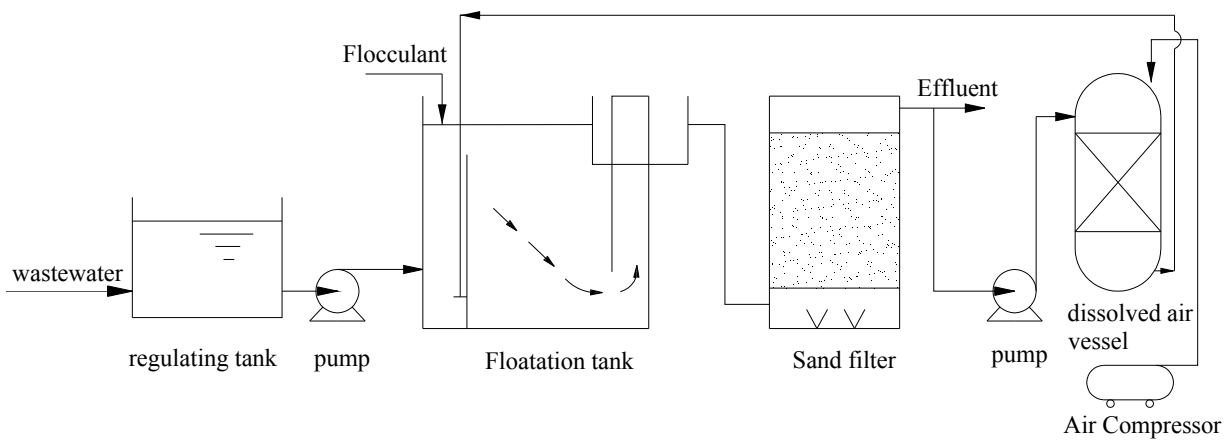
According to the oxygen requirements of the different bacteria, the bacteria can be divided into aerobic bacteria, anaerobic bacteria and facultative bacteria. Aerobic biological treatment can purify the water with the help of aerobic bacteria and facultative bacteria in the aerobic environment. Aerobic biological treatment can be divided into two major categories: activated sludge process and biofilm process.

Name	Dyes and Additives in sewage	Water Quantity (t/d)	Main Process	Amount of Coagulant (mg/L)	Water Quality		Treatment Efficiency	
					Color (times)	COD (mg/L)	Color (%)	COD (%)
A Knitting Mill in Kunming Yunnan	Naphthol, Direct dye, Acidic dye, Reactive dye	1000	wastewater → pump → mixed reaction tank PAC ↓ effluent ← sedimentation tank	60-80	70-120	267	>90	60
A Printing and Dyeing Mill in Shanghai	Vat dye, Naphthol, Dope	Pilot scale test	wastewater → regulating tank → pump → dissolved vessel → floatation tank → effluent	400	400	600-800	80-90	60
A Printing and Dyeing Mill in Beijing	Acidic dye, Disperse dye, Reactive dye, Sulfide dye	120	wastewater → regulating tank → coagulation tank → floatation tank → sand filter tank → effluent	—	174-347	228-352	97.41	74.69
A Silk and Dyeing Mill in Shaoxing, zhejiang	Disperse dye, Reactive dye, Direct dye, Sulfide dye, Acidic dye	500	wastewater → regulating tank → reaction tank → coagulation tank → tube sedimentation tank → effluent tank	FeSO <sub>4</sub> : 0.7kg/t sewage, Lime: 0.38kg/t sewage.	720-830	1114-1153	92	55-59

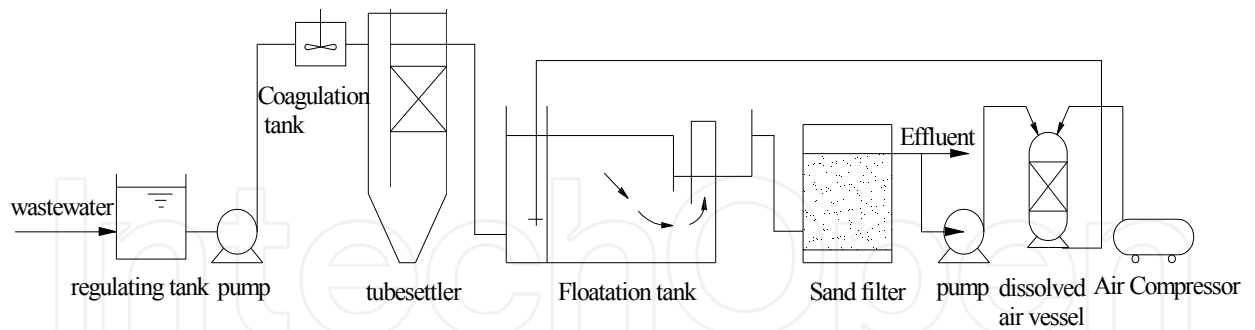
Table 8. Physicochemical treatment instance of textile dyeing wastewater



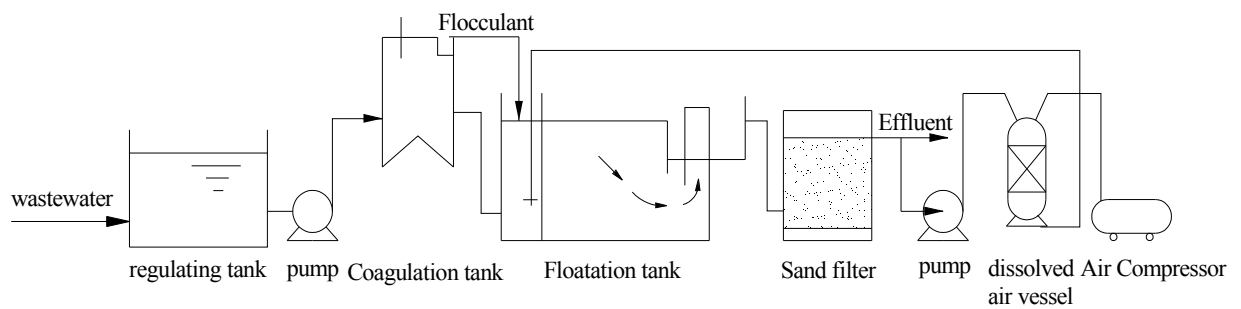
(a)



(b)



(c)



(d)



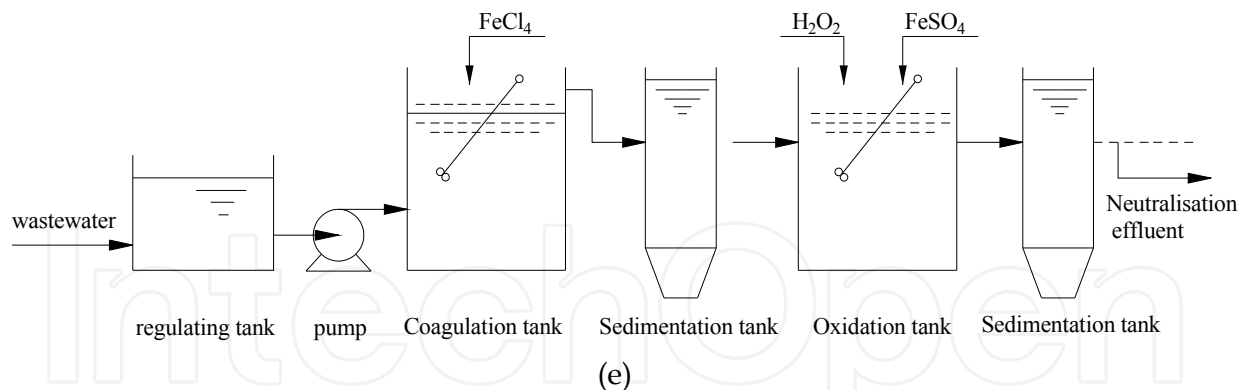


Fig. 2. The physicochemical treatment process in textile dyeing wastewater

### 2.2.1.1 Activated sludge process

Activated sludge is a kind of floc which is mainly comprised of many microorganisms, which has strong decomposition and adsorption of the organics, so it is called “activated sludge”. The wastewater can be clarified and purified after the separation of activated sludge. Activated sludge process is based on the activated sludge whose main structure is the aeration tank.

Activated sludge Process is an effective method. As long as according to the scientific laws, after getting some experiences, higher removal efficiency can be got. In present treatment, the oxidation ditch and SBR process are the commonly used activated sludge process.

#### Oxidation ditch process

Oxidation ditch is a kind of biological wastewater treatment technology, which developed by the netherlands health engineering research institute in the 50's of last century. It is a variant of activated sludge, which is a special form of extended aeration. The oxidation ditch plan was shown in Fig. 3. And the biological sewage treatment process which mainly composed by the oxidation ditch, as was shown in Fig. 4.

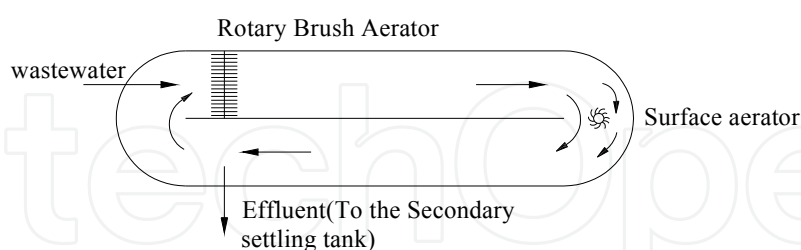


Fig. 3. Oxidation ditch plan

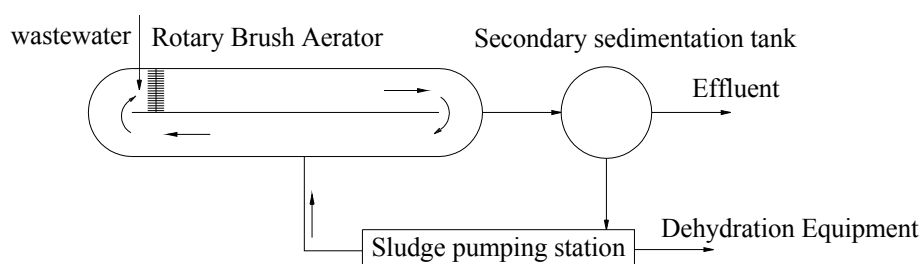


Fig. 4. The oxidation ditch for the biological treatment process

The oxidation ditch is generally consisted of the ditch body, aeration equipment, equipment of the water in or out, diversion and mixing equipment. The shape of the ditch body is usually ring; it also can be rectangular, L-shaped, round or other shape. The side shape of the oxidation ditch generally is rectangular or trapezoidal. Wastewater, activated sludge, and various microorganisms are mixed in a continuous loop ditch in order to complete nitrification and denitrification. Oxidation ditch has the characteristics of completely mixed, plug-flow and oxidation tank. Since oxidation ditch has long hydraulic retention time(HRT), low organic loading and long sludge age, compared to conventional activated sludge process, the equalization tank, primary sedimentation tank, sludge digestion tank can be omitted. The secondary sedimentation tank also can be omitted in some processes. It has many characteristics, such as high degree of purification, impact resistance, stable, reliable, simple, easy operation and management, easy maintenance, low investment and energy consumption. Oxidation ditch forms aerobic zone, anoxic zone and the anaerobic zone in space, which has a good function of denitrification.

### Sequencing Batch Reactor Activated Sludge process

Sequencing Batch Reactor Activated Sludge Process (SBR Process) is a reform process from activated sludge, which is a new operating mode. Its operation is mainly composed of five processes: ①inflow; ②reaction; ③sedimentation; ④outflow; ⑤standby. The reaction process plan has been showed in Fig. 5.

SBR treatment process not only has a high removal rate of COD, but also has a high removal efficiency of color. Compared to the traditional methods, using SBR process has the following advantages (Li-yan Fu et al.,2001):

- i. It has great resistance to shock loading. The reserved water can effectively resist the impact of water and organic matter.

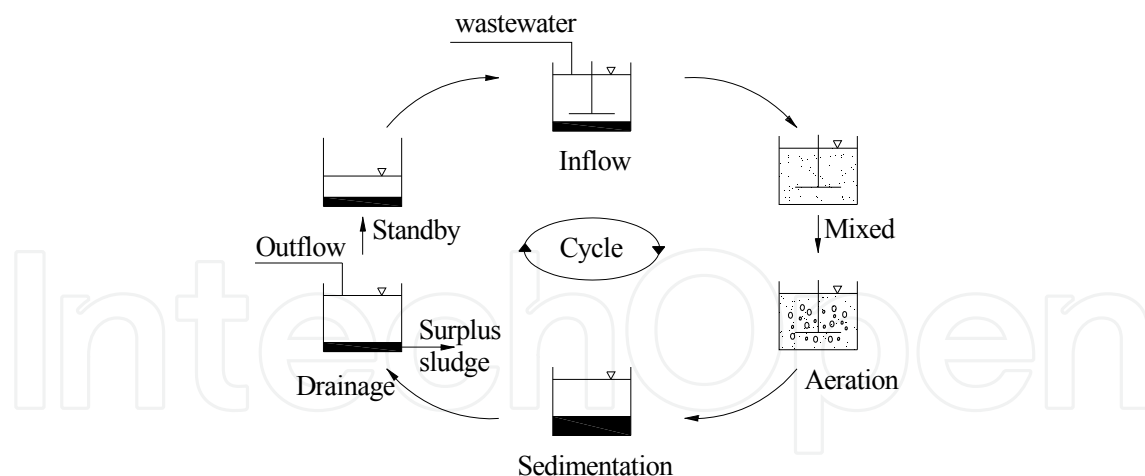


Fig. 5. Reaction process of SBR

- ii. Flexible control. The run time, the total residence time and gas supply of each stage can be adjusted according to the quantity of inflow or outflow.
- iii. The activated sludge has good traits and low sludge production rate. Since the original water contains many organic matters, which is suitable for the bacteria to grow, the sludge is in good characters. In the standby period, the sludge is in the endogenous respiration phase, so the sludge's yield is low.
- iv. It has less processing equipment, simple structure, and it is easy to be operated.

items	wastewater	Effluent	Removal rate
CODcr(mg/L)	689	61.2	91.2
Color(times)	800	50	93.8
SS(mg/L)	384.3	32.6	91.5

Table 9. The removal efficiency of various indicators in this dyeing factory

There is a dyeing factory in Jiangsu, which produces 60,000 tons wastewater each year. The wastewater mainly comes from dyeing and rinse. The major pollutant in wastewater is seriously exceeded, such as COD, color and SS. The wastewater treatment process which is used in this factory has been shown in Fig.2.5. Through this process, its various indicators have been shown in table 9(Haidong Jia,2003).

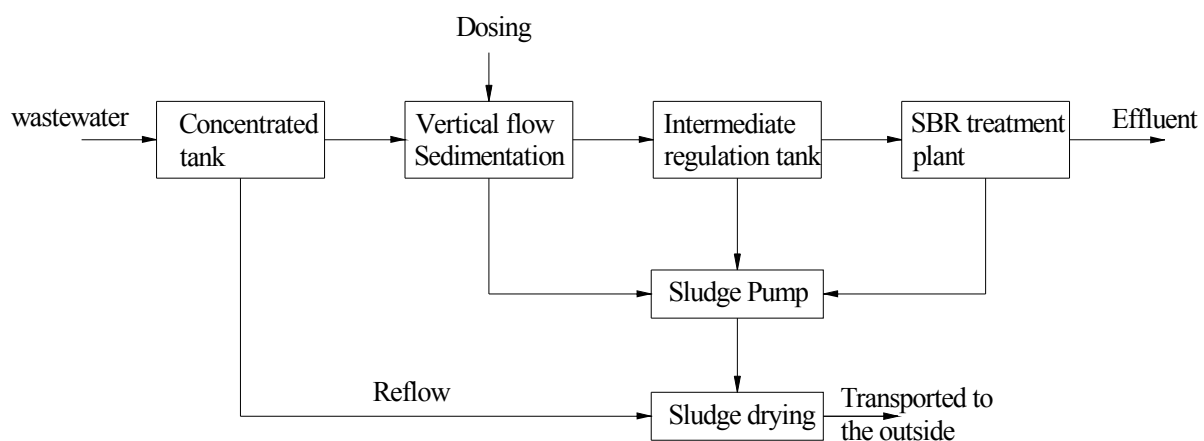


Fig. 6. The wastewater treatment process based on SBR

### 2.2.1.2 Biofilm

The biofilm process is a kind of biological treatment that making the numerous microorganisms to attach to some fixed object surface, while letting the wastewater flow on its surface to purify it by contact. The main types of the biofilm process are biological contact oxidation, rotating biological contactors and biological fluidized bed.

#### Biological contact oxidation

Biological contact oxidation is widely used in the dyeing wastewater treatment. The main feature of the process is to set fillers in the aeration tanks, so that it has the characteristics of activated sludge and biofilm. The wastewater in oxidation tank contains a certain amount of activated sludge, while the fillers are covered with a large number of biofilm. When the wastewater contact with the fillers, it can be purified under the function of aerobic microorganisms.

1. The main features of the biological contact oxidation tank are as following:
  - i. It has a efficient purification, a short processing time as well as a good and stable water quality.
  - ii. It has a higher ability to adapt the impact load. Under the intermittent operating condition, it is still able to maintain good treatment effect. To uneven drainage enterprises, it has more actual significance.
  - iii. Its operation is simple, convenient and easy maintenance. It don't have sludge return, sludge bulking phenomenon or any filter flies.

iv. It produce less sludge and the sludge particles is larger ,which is easier to be sedimentated

## 2. The form of biological contact oxidation

According to the different direction of the influent and aeration, the design form of the biological contact oxidation can be divided into two types: one is the same flow contact process which makes the wastewater and air flow into the contact tank bottom (Fig. 7). This process can guarantee the volume load about 4.5 kgBOD/m<sup>3</sup>. Another is the reverse flow contact process which let the air flow into the bottom, and let the wastewater into the top(Fig. 8). This process can guarantee the volume load about 8 kgBOD/m<sup>3</sup>.

## 3. The choice of filler

The filler is not only related to the treatment effect, but also affects the project investment. The surface area, bio-adhesion and whether easily blocked of the filler are undoubtedly the most important conditions, but the economy is also an important factors. The filler in the oxidation tank is the proportion of investment accounted for relatively large, so the price is often the first consideration. For example, the technical performance of some filler is slightly worse, but the price is cheap. The contact time can be increased appropriately. Commonly used fillers are honeycomb packing, corrugated board packing equipment, soft and semi-soft filler.

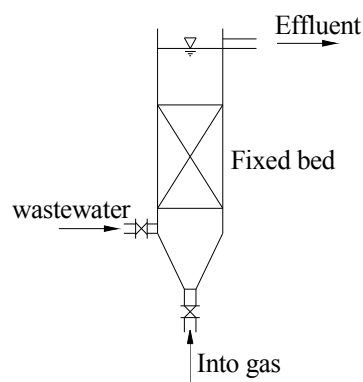


Fig. 7. The schematic diagram of the same flow contact

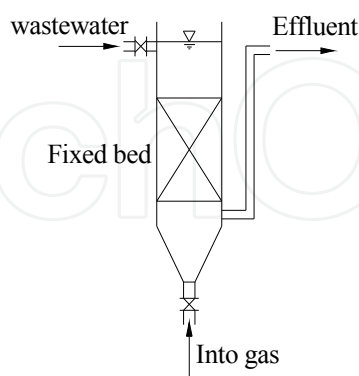


Fig. 8. The schematic diagram of the reverse flow contact

## Rotating Biological Contactor

Rotating Biological Contactor is an efficient sewage treatment plant developed on the basis of the original biological filter. It is constituted by a series of closed disks which are fixed on a horizontal axis (Fig. 9). The disks are made of lightweight materials, such as hard plastic

plate, glass plate etc. The disk diameter is about 1-3m generally. Nearly half of the disk area is submerged in the sewage of the oxidation tank, but the upper half is exposed to the air. The rotating horizontal axis which is driven by the Rotating device makes the disk rotating slowly. Due to the disk's rotating, the sewage in the oxidation tank is completely mixed. There is a layer of biofilm on the disk surface, when the rotating disk immersed in the sewage inside of the oxidation tank, the organic matter in the sewage would be adsorbed by the biofilm on the disk. When the rotating disk rotate to the air, the water film which is brought up by the disk will drip down along the biofilm surface, at the same time, the oxygen in the air will dissolve into the water film constantly. Under the catalysis of enzyme, though absorbing the dissolved oxygen in the water film, microorganism can oxidate and decompose the organic matter in the sewage and excrete the metabolite at the same time. In the process of disk rotation, the biofilm on the disk get in touch with the sewage and the air constantly alternating, completing the process of adsorption-oxidation-oxidative decomposition continuously to purify the sewage. The advantages of the Biological Rotating Contactor are power saving, large shock load capability, no sludge return, little sludge generated, little noise, easy maintenance and management and so on. On the contrary, the shortcomings are the large area and needing the maintain buildings.

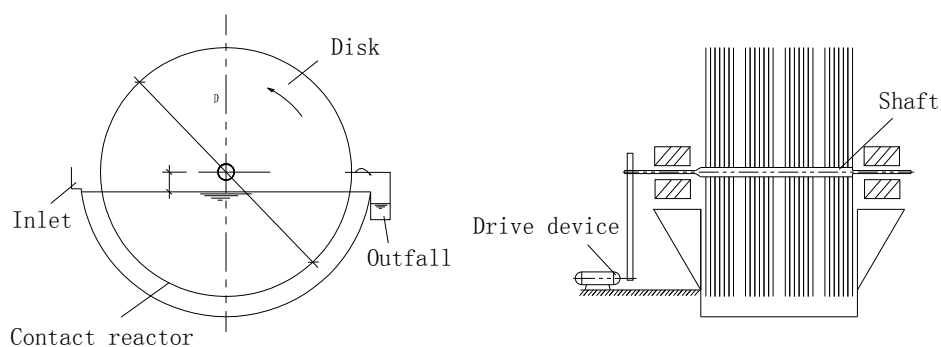


Fig. 9. The schematic diagram of biological rotating disk

The main parameters of affecting the process performance are rotate speed, sewage residence time, reactive tank stage, disk submergence and temperature.

Towards the low consistency sewage whose BOD consistency is under 300 mg/L, when the rotate speed is under 18 m/min, the disposal efficiency would enhance with the rotate speed increase, otherwise, it would not be any improving. Toward high-BOD consistency sewage, increasing the rotate speed is equivalent to increase the contact, oxidation and stirring. So, it improves the efficiency. On the other hand, increasing the rotate speed increase the energy consumption shapely, so we must do full economic comparison between increasing energy consumption and increasing land acreage.

### Biological fluidized bed

Fluidized bed process is also called suspended carrier biofilm process, which is a new efficient sewage treatment process. The method which adopts the solid particles fluidization technology can keep the whole system at a fluidized state to enhance the contact of solid particles and fluid and achieve the purpose of sewage purification. The substance of this method is that using activated carbon, sand, anthracite or other particles whose diameter is less than 1mm as the carrier and filling in the container. Through pulse water, the carrier is made into fluidization and covered by the biofilm on its surface. Due to the small size of the

carrier, it has a great surface area in unit volume (the carrier surface area can reach 2000-3000  $\text{m}^2/\text{m}^3$ ), and can maintain a high level of microbial biomass. The treatment efficiency is about 10-20 times higher than conventional activated sludge process. It can remove much organic matter in short time, but the land acreage is only about 5% of the common activated sludge process. Therefore, in the treatment of high consistency organic wastewater in the textile dyeing wastewater, we can consider adopting this suspended carrier fluidized bed process.

### 2.2.2 Anaerobic biological treatment

Anaerobic biological treatment process is a method that make use of the anaerobic bacteria decompose organic matter in anaerobic conditions. This method was first used for sludge digestion. In recent years it was gradually used in high concentration and low concentration organic wastewater treatment. In textile industry, there are many types of high concentration organic wastewater, such as wool washing sewage, textile printing and dyeing wastewater etc., which the organic matter content of it is as high as 1000 mg/L or more, the anaerobic wastewater treatment process can achieve good results. The anaerobic-aerobic treatment process is usually adopted in actual project that is using anaerobic treatment to treat high concentration wastewater, and using aerobic treatment to treat low concentration wastewater. Currently, the hydrolysis acidification process is the main anaerobic treatment process, which can increases the biodegradability of the sewage to facilitate the following biological treatment process.

The hydrolysis acidification process is the first two stages of the anaerobic treatment. Through making use of the anaerobic bacteria and facultative bacteria, the macromolecule, heterocyclic organic matter and other difficult biodegradable organic matter would be decomposed into small molecular organic matter, thereby enhancing the biodegradability of the wastewater and destructing the colored groups of dye molecules to remove part of the color in wastewater. More importantly, due to the molecular structure of the organic matter and colored material or the chromophore has been changed by the anaerobic bacteria, it's easy to decompose and decolor under the aerobic conditions, which improve the decolorization effect of the sewage. Operating data shows that the pH value of the effluent from hydrolysis tank usually decrease 1.5 units. The organic acid which is produced in hydrolysis can effectively neutralize some of the alkalinity in wastewater, which can make the pH value of sewage drop to about 8 to provide a good neutral environment for following aerobic treatment. Currently, the anaerobic digestion process is a essential measure in the biological treatment of textile dyeing wastewater.

In addition, there are many other processes used in textile dyeing wastewater treatment currently, such as upflow anaerobic sludge bed(UASB), upflow anaerobic fluidized bed (UABF), anaerobic baffled reactor (ABR) and anaerobic biological filter and so on.

### 2.3 Biochemical and physicochemical combination processes

In recent years, as the application of new technologies in textile and dyeing industry, a large number of difficult biodegradable organic matter such as PVA slurry, surface active agents and new additives enter into the dyeing wastewater, which result in the high concentration of the organic matter, complex and changeable composition and the obvious reduction of the biodegradability. The  $\text{COD}_{\text{Cr}}$  removal rate of the simple aerobic activated sludge process which was used to treat the textile dyeing wastewater has decreased from 70% to 50%, and the effluent can not meet the discharge standards. More seriously, quite a number of sewage treatment facilities can't normally operate even stop running. Therefore, the biochemical



and physicochemical combination processes has been gradually developed. And its application is increasingly widespread (Sheng-Jie You et al.,2008). The types of the combination process are various, and the main adoptions currently are as following:

### 2.3.1 Hydrolytic acidification-contact oxidation-air floatation process

This combination process is a typical treatment process of the textile dyeing wastewater, which is widely used (The process flow diagram is shown in Fig. 10).The wastewater firstly flows through the bar screen, in order to remove a part of the larger fibers and particles, and Then flows into the regulating tank. After well-distributed through a certain amount of time, the sewage flows into the hydrolysis acidification tank to carry out the anaerobic hydrolysis reaction. The reaction mechanism is making use of the anaerobic hydrolysis and acidification reaction of the anaerobic fermentation to degrade the insoluble organic matter into the soluble organic matter by controlling the hydraulic retention time. At the same time, through cooperating with the acid bacteria, the macromolecules and difficult biodegradable organic matter would be turned into biodegradable small molecules, which provide a good condition for the subsequent biological treatment. Next, the sewage enters into the biological contact oxidation tank. After the biochemical treatment, the wastewater directly enters into the flotation tank for flotation treatment, which is adopted the pressurized full-dissolved air floatation process. The polymer flocculants added in flotation tank react with the hazardous substances, which can condense the hazardous substances into tiny particles. Meanwhile, sufficient air is dissolved in the wastewater. And then the pressure suddenly is released to produce uniformly fine bubbles, which would adhere to the small particles. The density of the formation is less than  $1\text{kg}/\text{m}^3$ , which can make the formation float and achieve the separation of the solid and liquid.

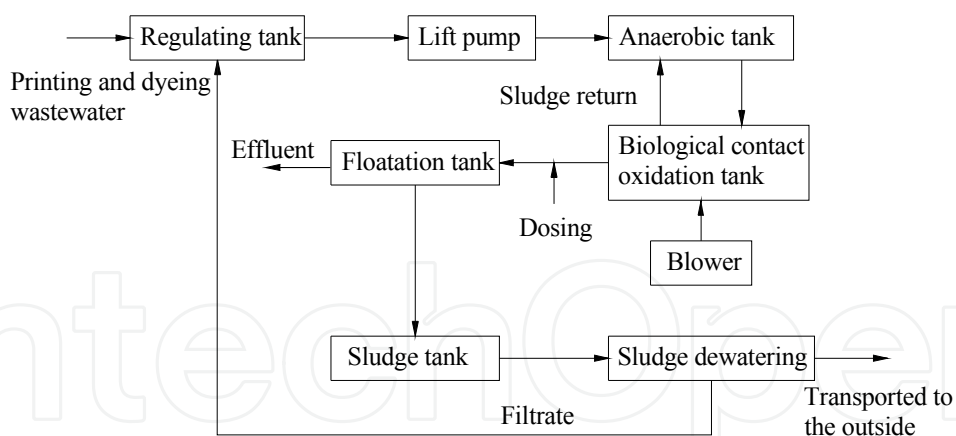


Fig. 10. The process flow diagram

The anaerobic hydrolysis acidification tank equipped with semi-soft padding and the biological contact oxidation tank equipped with the new SNP-based filler. The following physicochemical treatment uses the dosing flotation tank, which has four characteristics. Firstly, the deciduous biofilm and suspended solids removal rate can reach 80% to 90%. Secondly, the color removal rate can reach 95%. Thirdly, the hydraulic retention time in the flotation tank is short, which is only about 30 min, while the precipitation tank is about 1.15 h to 2 h, so the volume and area of the flotation tank is small. Finally, the sludge moisture content is low, only about 97% to 98%, which can be directly dewatered. But the flotation

treatment need an additional air compressor, pressure dissolved gas cylinders, pumps and other auxiliary system. The operation and management is also relatively complicated.

After the treatment of this process, the  $COD_{Cr}$  removal rate can be up to 95% or more. The actual effluent quality is about:  $pH=6\sim9$ ,  $color<100$ times,  $SS<100$ mg/L,  $BOD_5<50$ mg/L,  $COD_{Cr}<150$ mg/L (Honglian Li, 2006).

### 2.3.2 Anaerobic-aerobic-biological carbon contacts

The treatment process is a mature and widely used process in wastewater treatment in recent years (the process shown in Fig. 11). The anaerobic treatment here is not the traditional anaerobic nitrification, but the hydrolysis and acidification. The purpose is aiming at degrading some poorly biodegradable polymer materials and insoluble material in textile dyeing wastewater to small molecules and soluble substances by hydrolysis and acidification, meanwhile, improving the biodegradability and  $BOD_5/COD_{Cr}$  value of the wastewater in order to create a good condition for the subsequent aerobic biological treatment. At the same time, all sludge generated in the aerobic biological treatment return into the anaerobic biological stage through the sedimentation tank. Because of the sludge in the anaerobic biochemical stage has sufficient hydraulic retention time (8h~10h) to carry out anaerobic digest thoroughly, The whole system would not discharge sludge, that is the sludge achieve its own balance (Note: only a small amount of inorganic sludge accumulate in the anaerobic stage, but do not have to set up a special sludge treatment plant).

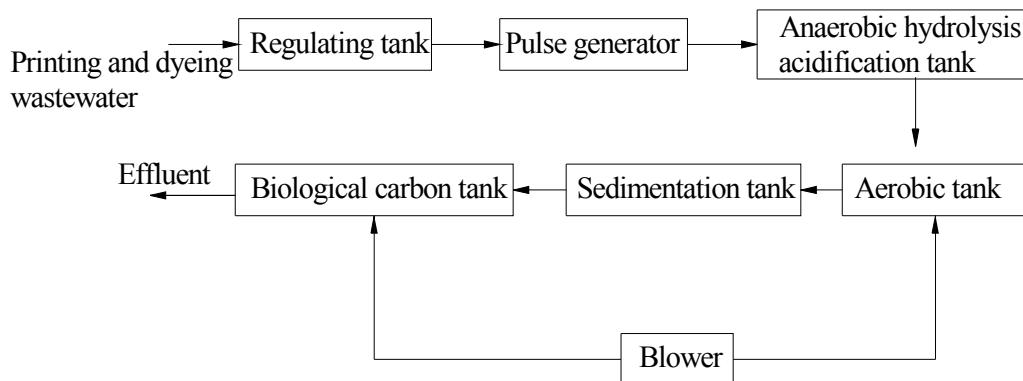


Fig. 11. The process flow diagram

Anaerobic tank and aerobic tank are both installed media, which is a biofilm process. Biological carbon tank is filled with activated carbon and provided oxygen, which has the characteristics both of suspended growth method and fixation growth method. The function of pulse water is mixing in the anaerobic tank. The hydraulic retention time of various parts is about:

- Regulating tank: 8h~12h; anaerobic biochemical tank: 8h~10h
- Aerobic biochemical tank: 6~8h; biological carbon tank: 1h~2h
- Pulse generator interval: 5min~10min.

According to the textile dyeing wastewater standard ( $COD_{Cr}\leq 1000$ mg/L), the effluent can achieve the national emission standards, which can be reused through further advanced treatment. For the five years operation project, the results show that the operation is normal, the treatment effect is steady, there is no efflux of sludge and the sludge was not found excessive growth in the anaerobic biochemical tank.

### 2.3.3 Coagulation-ABR-oxidation ditch process

The treatment has been adopted widely currently, such as a textile dyeing wastewater treatment plant in Jiangmen of Guangdong Province (the process is shown in Fig. 12).

The characteristics of the textile dyeing plant effluent are the variation in water, the higher of the alkaline, color and organic matter concentration, and the difficulty of the degradation ( $BOD_5/COD_{Cr}$  value is about 0.25). The workshop wastewater enter into the regulating tank by pipe network to balance the quantity and quality, after wiping off the large debris by the bar screen before the regulating tank. The adjusted wastewater flow into the coagulation reaction tank, at the same time, the  $FeSO_4$  solution was added into it to carry out chemical reaction. Finally, the effluent flows into the primary sedimentation tank for spate separation, meanwhile enhancing the  $BOD_5/COD_{Cr}$  ratio.

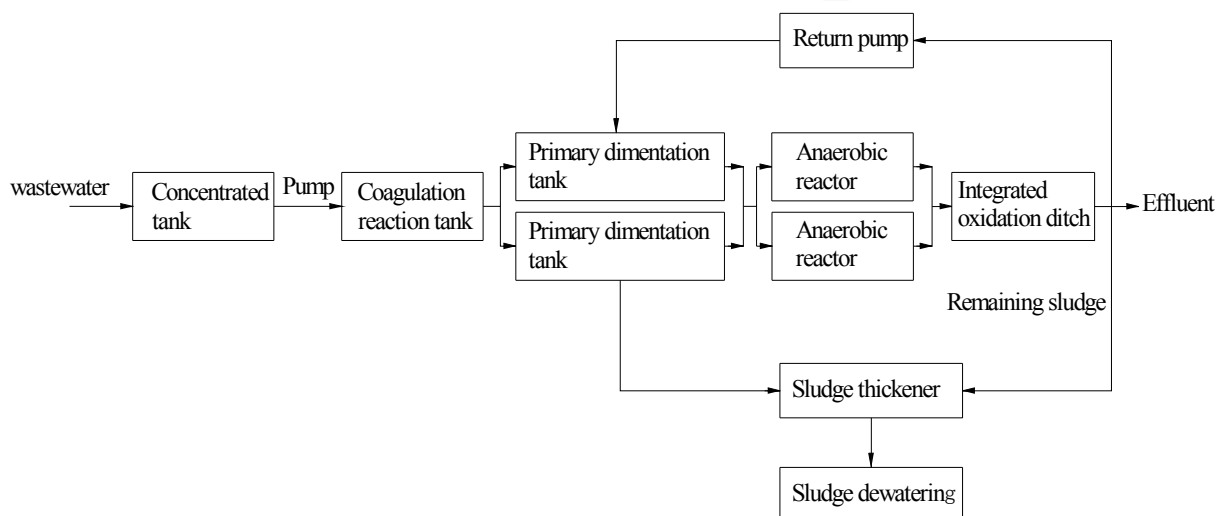


Fig. 12. The process flow diagram

The effluent of primary sedimentation tank flows into the anaerobic baffled reactor (ABR) by gravity. After the anaerobic hydrolysis reaction, it enters into the integrated oxidation ditch for aerobic treatment, and then goes into the secondary sedimentation tank for spate separation. The upper liquid was discharged after meeting the standards, but the settled sludge was returned to the return sludge tank, most of which was returned to ABR anaerobic tank by pump. The remaining sludge was pumped to the sludge thickening tank for concentration.

Since the using of this sewage treatment process, the treatment effect is stable. The removal rate of each index is high, and the operation situation of each unit is shown in Table10 (Wu Zhimin&Zhangli, 2009).

Process	PH	CODcr (mg/L)	BOD <sub>5</sub> (mg/L)	SS (mg/L)	Color (times)
Wastewater	9-13	1800-2000	400-500	250-350	500
Coagulation effluent	6-9	1327	344	157	102
ABR effluent	6-9	532	292	94	48
Aerobic secondly sedimentation effluent	6-9	80	15	14	30

Table 10. Average Quality of Each Process Effluent

### 2.3.4 UASB-aerobic-physicochemical treatment process

For the high pH value dyeing wastewater treatment systems, we should adjust the pH value to the range from 6 to 9 before entering the treatment system. While towards the difficultly biodegradable textile dyeing wastewater, effective measures should be taken to increase the biodegradability. At the same time, the volume of the regulating tank must be increased (this is repeatedly demonstrated in engineering practice) to guarantee the water quantity, quality and color achieving a relatively uniform towards changeable dyeing wastewater. Good inflow condition can be created for following process though this method. Therefore, we put forward the "UASB-aerobic-physicochemical method" treatment process in the actual project, and the technological process is shown in Fig. 13.

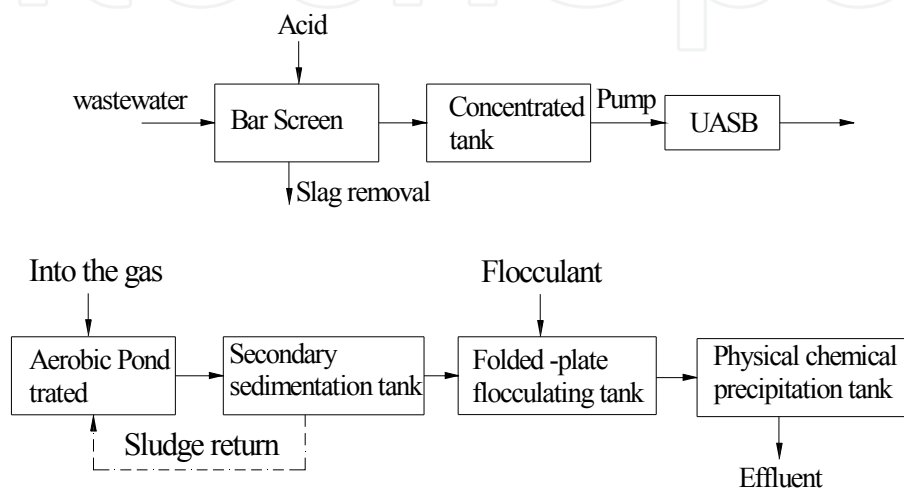


Fig. 13. The process flow diagram

At present, the treatment process has been applied in a number of textile dyeing factory, such as a Jiangyin textile dyeing factory, which sewage component is complex. Before the sewage enters into the regulating tank, the suspended particles in which must be removed by bar screen, at the same time, an appropriate amount of acid was added to adjust the pH value of the sewage. Then adjusting the water quantity and quality to make it uniformed. After pretreatment, the textile dyeing wastewater carries out anaerobic reaction firstly in UASB reactor to improve the biodegradability of wastewater and the decolorization rate, and then flows into the aerobic tank. In the aerobic tank, the organic matter in sewage is removed. Finally, in order to ensure the effective removal of the suspended particles particular the activated sludge, some flocculants was added in the sedimentation tank to improve its effect. Through this sewage treatment process, the removal rate of pollutants is shown in table 11 (Kerong Zhang, 2007).

Items	(raw water) regulating tank	Biochemical treatment system		Physicochemical treatment system	
		Effluent	Removal rate	Effluent	Removal rate
PH	8-12	7-8		6-9	
COD <sub>Cr</sub> (mg/L)	1000-2000	100-200	90	≤100	50
BOD <sub>5</sub> (mg/L)	300-600	15-30	95	≤30	
Color(times)	100-600	60	80	≤40	35

Table 11. The removal of the processing units

## **2.4 Cutting-edge treatment process**

### **2.4.1 Photochemical oxidation**

Photochemical oxidation has many advantages of the mild reaction conditions (ambient temperature and pressure), powerful oxidation ability and fast speed, etc. It can be divided into 4 kinds, which are light decomposition, photoactivate oxidation, optical excitation oxidation and photocatalysis oxidation. Among them, the photocatalysis oxidation has been more researched and applied currently.

This technology can effectively destroy a lot of organic pollutants whose structure is stable and difficult to biologically degrade. Compared with the physical treatment in traditional wastewater treatment process, the most obvious advantages of this technology are significant energy efficiency, completely pollutants degradation and so on. Almost all of the organic matter can be completely oxidized to  $\text{CO}_2$ ,  $\text{H}_2\text{O}$  and other simple inorganic substances under the light catalyst. However, towards high concentration wastewater, the effect of the photocatalysis oxidation process is not ideal. The research about photocatalysis oxidation degradation of dye mainly focused on the study of photocatalyst.

### **2.4.2 Electrochemical oxidation**

The mechanism of the electrochemical process treating dyeing wastewater is making use of electrolytic oxidation, electrolytic reduction, electrocoagulation or electrolytic floating destruct the structure or the existence state to make it bleached. It has the advantages of small devices, small area covering, operation and management easily, higher  $\text{COD}_{\text{Cr}}$  removal rate and good bleaching effect, but the precipitation and the consumption of electrode material is great, and the operating cost is high. The traditional electrochemical methods can be divided into power flocculation, electrical float, electro-oxidation, micro-electrolysis and the electrolysis method. With the development of electrochemical technologies and the appearing of a variety of high-efficiency reactor, the cost of treatment will decrease largely. Electro-catalytic advanced oxidation process (AEOP) is a new advanced oxidation technology developed recently. Because of its high efficiency, easy operation, and environmental friendliness, it has attracted the attention of researchers. Under normal temperature and pressure, it can produce hydroxyl radicals directly or indirectly through the reactions in the catalytic activity electrode, thus the degradation of the difficultly biodegradable pollutants is effective. It is one of the main directions in future research.

### **2.4.3 Ultrasonic technology**

Using ultrasonic technology can degrade chemical pollutants, especially the refractory organic pollutants in water. It combines the characteristics of advanced oxidation technology, incineration, supercritical water oxidation and other wastewater treatment technologies. Besides the degradation conditions are mild, degradation speed is fast and application widely, it can also use individually or combined with other water treatment technologies. The principle of this method is that the sewage enters into the air vibration chamber after being added the selected flocculants in regulating tank. Under the intense oscillations in nominal oscillation frequency, a part of organic matter in wastewater is changed into small organic molecule by destructing its chemical bonds. The flocculants flocculation rapidly accompanied with the color,  $\text{COD}_{\text{Cr}}$  and the aniline concentration was fall under the accelerating thermal motion of water molecules, which play the role of reducing organic matter concentration in wastewater. At present, the ultrasonic technology in the research of water treatment has achieved great achievements, but most of them are still confined to laboratory research level.



#### 2.4.4 High energy physical process

High energy physical process is a new wastewater treatment technology. When the high-energy particle beam bombard aqueous solution, the water molecules would come up with excitation and ionization, produce ions, excited molecules, secondary electrons. Those products would interact with each other before spreading to the surrounding medium. It would produce highly reactive HO• radicals and H atoms, which would react with organic matter to degrade it. The advantages of using high-energy physics process treat dyeing wastewater are the small size of the equipment, high removal rate and simple operation. However, the device used to generate high energy particle is expensive, technically demanding is high, energy consumption is big, and the energy efficiency is low and so on. Therefore, it needs a lot of research work before put into actual project.

### 3. Conclusions and recommendations

Current, the textile dyeing wastewater is one of the most important source of pollution. The type of this wastewater has the characteristics of higher value of color, BOD and COD, Complex composition, large emission, widely distributed and difficult degradation. If being directly discharged without being treated, it will bring serious harm to the ecological environment. Because of the dangers of dyeing wastewater, many countries have enacted strict emissions standards, but There is no uniform standard currently.

Waste minimization is of great importance in decreasing pollution load and production costs. This book has shown that various methods can be applied to treat cotton textile effluents and to minimize pollution load. Traditional technologies to treat textile wastewater include various combinations of biological, physical, and chemical methods, but these methods require high capital and operating costs. Technologies based on membrane systems are among the best alternative methods that can be adopted for large-scale ecologically friendly treatment processes. A combination methods involving adsorption followed by nanofiltration has also been advocated, although a major drawback in direct nanofiltration is a substantial reduction in pollutants, which causes permeation through flux.

It appears that an ideal treatment process for satisfactory recycling and reuse of textile effluent water should involve the following steps. Initially, refractory organic compounds and dyes may be electrochemically oxidized to biodegradable constituents before the wastewater is subjected to biological treatment under aerobic conditions. Color and odor removal may be accomplished by a second electrooxidation process. Microbial life, if any, may be destroyed by a photochemical treatment. The treated water at this stage may be used for rinsing and washing purposes; however, an ion-exchange step may be introduced if the water is desired to be used for industrial processing.

As the improvement of the environmental protection laws and the raise of the awareness of environmental protection, the pollution of printing and dyeing enterprises has caught a lot of attention and the treatment of dyeing wastewater has become a focus. Recently, except the oxidation, filtration and other single method research, it has been introduced a large number of electric, magnetic, optical and thermal method to treat the refractory materials. Several of other techniques have also been carried out to treat the wastewater in order to develop a variety of ways. The interdisciplinary study based on the traditional biological approach will be the direction of the wastewater treatment. The writer expected that the technology which is efficient, clean and reasonable will come out soon.

On the other hand, clean production is also an important research, which can shift the focus from end of the treatment to the prevention of pollution and conduct more in-depth



research on the printing and dyeing production technology and process management. Moreover, the strategic, comprehensive, preventive measures and advanced production technology can be used to improve the material and energy utilization. Also, we can reduce and eliminate the generation and emissions of wastes as well as the production of excessive use of resources and the risks to humans and the environment.

Prevention and treatment of dyeing wastewater pollution are complementary. We can both use preventive measures as well as a variety of methods to control the wastes and make use of treated water. This will not only reduce water consumption, but also effectively reduce the pollution of the printing and dyeing wastewater and achieve sustainable development of society.

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## **Advances in Treating Textile Effluent**

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The treatment of textile wet processing effluent to meet stringent governmental regulations is a complex and continually evolving process. Treatment methods that were perfectly acceptable in the past may not be suitable today or in the future. This book provides new ideas and processes to assist the textile industry in meeting the challenging requirements of treating textile effluent.

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