DEVELOPMENT OF BIOLOGICAL TREATMENT SYSTEM FOR REDUCTION OF COD FROM TEXTILE WASTEWATER

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ABSTRACT

Wastewater from industrial plants such as textile, electroplating and petroleum refineries can contain various substances that tend to increase the chemical oxygen demand (COD) of the wastewater. Various local agencies have placed limits on the allowable levels of COD in industrial wastewater effluent. It is desired to develop a process suitable for treating the wastewater to meet the regulatory limits. Various methods are available for COD reduction in industrial wastewater such as precipitation, incineration, chemical oxidation and biological oxidation. This project attempts to solve the high concentration of COD in industrial wastewater using bacteria. The organic matter that contributed to COD in the wastewater will be degraded by the bacteria under aerobic conditions using batch process. The wastewater will be supplemented with an agricultural liquid waste for bacterial growth and metabolism. This will ensure the continual presence of bacteria to carry out degradation of organic matter in the wastewater.

ABSTRAK

Air sisa industri seperti industri tekstil, elektroplat, dan penapisan petroleum mengandungi pelbagai bahan yang menyumbang kepada peningkatkan COD. Pelbagai agensi tempatan telah meletakkan had ke atas tahap COD yang dibenarkan dalam pengaliran keluar air sisa industri. Oleh itu, wujudnya keperluan untuk membangunkan proses yang bersesuaian bagi merawat air sisa tersebut supaya mencapai tahap pelepasan air sisa yang dibenarkan. Terdapat pelbagai kaedah yang boleh digunakan bagi pengurangan COD dalam air sisa industri seperti pemendakan, pengoksidaan kimia, dan pengoksidaan biologi. Projek ini dibangunkan untuk menyelesaikan masalah kandungan COD yang tinggi dalam air sisa industri dengan menggunakan bakteria. Bahan organik yang menyumbang kepada COD dalam air sisa akan dikurangkan oleh bakteria ini. Sumber nutrien yang dibekalkan ialah air sisa nenas. Ini adalah untuk memastikan perkembangan populasi bakteria yang berterusan bagi menjalankan proses pengurangan bahan organik di dalam air sisa.

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LIST OF ABBREVIATIONS AND SYMBOLS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
TSS	Total suspended solid
NB	Nutrient broth
OD	Optical density
CFU	Colony forming unit
L	Liter
g	Gram
mg	milligrams
rpm	Rotation per minute
^{o}C	Degree Celsius
mL	Milliliters
mg/L	Milligrams per liter
kPa	Kilo Pascal
ppm	Parts per million
Cr (IV)	Chromium (IV)
Cu (II)	Copper (II)
DDW	Distilled deionized water
TNTC	Too numerous to count
IB	Indigenous bacteria

AB	*Acinetobacter baumannii*
AC	*Acinetobacter calcoaceticus genospecies* 3
CC	*Cellulosimicrobium cellulans*
M	Mixed culture
A.baumannii	*Acinetobacter baumannii*
A.calcoaceticus	*Acinetobacter calcoaceticus genospecies* 3
C.cellulans	*Cellulosimicrobium cellulans*

CHAPTER I

INTRODUCTION

1.1 Textile industry

Textile industry can be classified into three categories, cotton, woolen, and synthetic fibers depending upon the raw materials used (Babu *et al*., 2000). Textile industries consume large volumes of water and chemicals for wet processing of textiles. The chemical reagents used are very diverse in chemical composition, ranging from inorganic compounds to polymers and organic products. In general, the waste water from textile industry is characterized by high value of BOD, COD, pH, and colour (Robinson *et al*., 2001).

Because of the high BOD, the untreated textile waste water can cause rapid depletion of dissolved oxygen if it is directly discharged into the surface water sources. Therefore the effluents with high COD level are toxic to biological life. The high alkalinity and traces of chromium where it was employed in dyes adversely affect the aquatic life and also interfere with the biological treatment process (Babu *et al*., 2000). Table 1.1 shows common characteristics for effluent emanated from textile industries (Zaharah *et al*,. 2004).

Table 1.1: Textile wastewater characteristics.

Parameter	Unit	Limit allowed for industrial discharge (Standard B)
Temperature	^{o}C	40
pH	-	5.5 -9.0
BOD	mg/L	50
COD	mg/L	100
TSS	mg/L	100
Nitrate	mg/L	7
Phosphate	mg/L	0.2
Sulphate	mg/L	-
Cr (III)	mg/L	1.0
Cu (II)	mg/L	1.0

* TSS-Total suspended solid Cr(III)-Cromium (III) Cu(II)-Copper(II)

1.2 Biodegradability of textile waste

The major sources of waste from textile operations can be contributed to the following activities, raw wool scouring, yarn and fabric manufacture, wool finishing, woven fabric finishing, and knitted fabric finishing. The chemicals normally used in textile processing are as follows:

1.2.1 Dyes

The most studied step in textile processing regarding the treatment of the effluent is the dyeing step. Dyeing causes an easy recognition of pollution via colour. A very small amount of dye is visible in water, decreasing the transparency of the water. In the environment this leads to inhibition of sunlight penetration and therefore of photosynthesis. In addition, industrial textile waste water presents the additional complexity of dealing with unknown quantities and varieties of many kinds of dyes, as well as low BOD/COD ratios, which may affect the efficiency of the biological decolorization (Babu *et al*., 2000).

1.2.2 Surface active agent

A series of research studies on biodegradation of surface active agents have been reviewed. For the biodegradation of surface active agents (surfactants) their hydrophobic groups are important. The hydrophobic ends are less fundamental for biodegradation but fundamental for their water solubility (Bisschops *et al*., 2003).

Biodegradation of surfactants are important because they interfere with effective oxygen transfer in biological treatment systems, they are characterized by relatively high aquatic toxicity and contribute to final BOD or COD of treated effluents (Bisschops *et al*., 2003).

Even though literature indicates that surfactants are more easily biodegradable than ever, they are still very difficult to degrade. For example, the surfactant alkylphenol ethoxylate is removed in activated sludge treatment and it was thought to be biodegradable. This surfactant is resistant to attack by bacteria found in activated sludge but it is effectively adsorbed on the sludge. The adsorption affected both the biodegradability and elimination. Thus most of the surface active agents used today are actually eliminated and not biodegraded by more than 80% 1 (Timothy *et al*., 1988).

1.2.3 Sizes

The hydrolysis of polyvinyl acetate (PVA) to yield water soluble alcohol produces PVA. PVA resists biodegradation when it contains small amounts of acetate groups in the polymer. The number and location of these residual groups may vary from batch to batch, causing the biodegradability to vary considerably. A portion of PVA is removed by sedimentation in the biological systems. Starch is readily biodegradable. Polyacrylates and CMC are partially removed by sedimentation in activated sludge. CMC degrades slowly with acclimatization. Polyacrylic and polyester sizes are recalcitrant to biodegradation (Robinson *et al*., 2001).

1.2.4 Finishing agents

Many different chemicals are used in treating textile fabric to impart desirable properties to final garment. The resin finishes have extremely low BOD values compared to their COD values. This may be caused by the presence of toxic chemicals or metal catalyst used in finish formulation. Most finishing agents are eliminated by adsorption or sedimentation in the biological treatment plants and not by biodegradation (Robinson *et al*., 2001).

1.2.5 Grease and oils

Oil and grease may present problems at the waste water treatment plant because they adhere to particulate matter, causing it to float. Not all oils are equally troublesome. Vegetable oils and natural grease tend to be fairly readily degradable.

The modern trend is towards lubricants based on petroleum and these materials are very much less easily degraded. Generally pretreatment for removal of these substances will not be required unless floating oil or grease is obviously present in the effluent. The naphthenic and paraffinic mineral oils are biodegradable with acclimatization. The silicon oil is not biodegradable. Waxes degrade slowly and the fatty esters are biodegradable (Bisschops *et al*., 2003).

1.2.6 Complexing agents

EDTA (ethylene diamene tetraacetate), which is the most widely used complexing agent, is very stable against oxidation and is not biodegradable. Due to its low molecular weight it is not adsorbed on activated sludge and escapes with effluent of the treatment plant (Timothy *et al*., 1988).

1.3 Textile Wastewater Treatment Current Technologies

There are many different unit operations employed for treatment of waste water from textile industries. Pretreatment for removal of inorganic solids and floating materials, flow equalization and neutralization, chemical coagulation, clarification, and biological treatment are the most common unit operations employed in the textile waste water treatment (Babu *et al*., 2000). For simplification, the operations treatment can be classified into chemical, physical, and biological treatment. These approaches along with their associated pros and cons are outlined in table 1.1 (Timothy *et al*., 1988).

__ **Table 1.2**. Textile Wastewater Treatment Current Technologies.

Current technologies	description	advantages	disadvantages
1. Biological large treatment	Activated sludge, Aerated lagoons, Land treatment, Extended aeration.	efficient BOD reduction	long residence times, aeration tanks, may require nutrient.
2. Chemical Precipitation	Percipitation-addition of multivalent cations with pH adjustment	heavy metals, suspended solid, BOD, COD	color removal varies with dye class, chemical handling problems.
3. Activated carbon	Passing water through a bed of carbon (as a pretreatment to further treatment)	BOD, COD, color	expensive, long residence times, low adsorption capacity.
4. Ultra filtration	Permeation of water under pressure through specialized polymeric membranes	BOD, COD, color	membranes foul easily, heavy metals not removed, need frequent cleaning.
5. Ozone	Ozone, generated by electrical discharged is used to oxidize organics	BOD, COD, color	very expensive, heavy metals and solids require separate treatment.

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1.4 COD reduction

1.4.1 Definition of COD

Bacteria require oxygen to breathe and oxidize organic substances; the total amount of which is called oxygen demand (Inoue, 2002). The level of COD is a critically important factor in evaluating the extent of organic pollution in textile waste water. Substantial sewer surcharges are often imposed when the local permitted limits are exceeded. Depending on the types of fibers, dyes, and additives, various textile operations will routinely generate water having high levels of COD (Timothy *et al.*, 1988).

In environmental chemistry, the chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water, making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution. Older references may express the units as parts per million (ppm) (Sawyer *et al*., 2003). Therefore, COD measures the potential overall oxygen requirements of the waste water sample including oxidizable components not determined in the BOD analysis (Timothy *et al*., 1988).

1.4.2 COD and BOD

The biochemical oxygen demand (BOD) test measures oxygen uptake during the oxidation of organic matter. It has wide applications in measuring waste loading of treatment plants and in evaluating the efficiency of treatment processes. It is of limited use in industrial waste water containing heavy metal ions, cyanide, and other substances toxic to microorganisms.

Although COD is comparable to BOD, it actually measures chemically oxidizable matter. Generally COD is preferred to BOD in process control applications because results are more reproducible and are available in a few minutes or hours rather than five days. In many industrial samples, COD testing may be the only feasible course because of the presence of bacterial inhibitors or chemicals that will interfere with BOD determination (Sawyer *et al*., 2003).

As dyeing process in textile is particularly difficult, acid dyes, fixing agents, thickeners, finishing agents, are required for successful colorization and cause major problems with the plant's effluents disposal in term of COD. Literature has shown that the removal of non-colored agents in textile industry effluent is more problematic, in terms of COD than visible dye agents (Walker *et al*., 2001).

1.5 Methods of COD reduction

The main source of organic substances, which contributes to COD in the effluent water, comes from the pretreatment of the raw materials. There are two ways to reduce organic substances in the effluent; recovery of organic materials from the effluent through ultrafiltration or electro-flocculation or by leasing using materials with low content of soluble organic substances can be found (Prasad Modak, 1998). Many approaches have been reported for COD removal of textile waste water ranging from chemical, physical, biological method and combined method.

1.5.1 Physical method

The physical treatment generally can be achieved via adsorption. The common adsorbents used in treating textile effluent are carbon, clay, and resin.

1.5.1.1 Granular activated carbon

In general granular activated carbon (GAC) processes have attracted interest for municipal waste water treatment for the removal of small concentrations of low molecular weight contaminants such as phenol from solution. But several researchers have since studied textile waste water treatment using GAC. They concluded that GAC adsorption was the best method for colour removal (Rozzi *et al*., 1999).

In many cases GAC adsorption is also coupled with ozonation or bio-ozonation in order to improve the removal treatment for textile waste. However there are papers which report, that GAC adsorption as sole treatment technique for COD removal from textile effluent. The adsorbent used was the GAC Filtrasorb 400. The adsorbent was washed in deionised water and sieved into 1000-4000 micrometer particle size range before contacting with the adsorbate solutions (Walker *et al*., 2001).

1.5.1.2 Membrane filtration

This method has the ability to clarify, concentrate and to separate dye continuously from textile effluent. But the concentrated residue left after separation poses disposal problems, and high capital cost and the possibility of clogging, and membrane displacements are disadvantages. This method of filtration is suitable for water recycling within textile dye plant if the effluent contains low concentration of dyes, but it is not effective to reduce dissolved solid content and COD content which makes water re-use a difficult task (Tim *et al*., 2001).

1.5.2 Chemical method

The waste water discharged from a dyeing process in the textile industry exhibits low BOD, high COD and high in colour. Hence, the need for chemical treatment is necessary in order to produce a more readily biodegradable compound. Chemical colour removal technique which are reported in the literature include adsorption by activated carbon, electrochemical treatment, ozonation, chemical precipitation, membrane filtration, hydrogen peroxide, Fenton's reagent and reverse osmosis (Ghoreishi *et al*., 2003).

1.5.2.1 Ozonation

Ozone is a powerful oxidizing agent that may react with organic compounds either directly or via radicals formed in a reaction chain as OH-radicals. Ozone can be used in waste water field to reduce COD, colour, toxicity, and pathogens and to improve waste water biodegradability and the coagulation-flocculation processes (Ciardelli *et al*., 2001).

Regarding COD removal, ozone treatment with 40 g O_3/m^3 at contact times of 15 min and 30 min causes the COD reductions from 160 to 53 and 203 to 123 mg/L respectively. In ozonation treatment, ozone generator will be fed with pure oxygen and contact with reactor filled up with waste water. The most important parameter to evaluate process feasibility is the ratio between the generated ozone and the eliminated COD. According to literature this parameter ranged between 1 and infinity. Value higher than 3 could make the oxidation process for COD elimination economically unfeasible (Bes-Pia *et al*., 2004).

However, ozonation shows effective results in decolorizing textile waste water compared to COD and BOD reduction. In addition, the cost of ozonation needs to be further ascertained to ensure the competitiveness of this method (Bes-Pia *et al*., 2004).

1.5.2.2 Electrochemical treatment

In recent years, there has been increasing interest in the use of electrochemical methods for the treatment of waste waters. Electrochemical methods have been successfully applied in the purification of several industrial wastewaters as well as textile effluent.

The electrolytic cell consisted of cathode and anode. In the past graphite was frequently used as an anode as it is economical and gives satisfactory results. Recently, titanium electrodes covered with very thin layers of electrodeposited noble metals have been used. Besides titanium, ruthenium, rhodium, and iridium mixture can also be applied as electrocatalysts for electro-oxidation of pollutants present in waste waters, making it possible to destroy organic pollutants which are difficult to eliminate biologically, such as phenols and surfactants (Bes-Pia *et al*., 2004).

1.5.2.3 Fenton reagent

Fenton's reagent is a suitable chemical means of treating waste waters which are resistant to biological treatment or is poisonous to live biomass. Chemical separation uses the action of sorption or bonding to remove dissolved dyes from textile effluent and has been shown to be effective in colour removal and also COD removal. But one major disadvantage of this method is generation of sludge through the flocculation of the reagent and the dye molecules used in dyeing stage (Tim *et al*., 2001).

The high cost and disposal problems have opened for development of new techniques. Application of conventional biological processes in the treatment of textile waste water has been extensively reported.

1.5.3 Biological method

Industrial biological waste water treatment systems are designed to remove the dissolved organic load from the waters using microorganisms. The microorganisms used are responsible for the degradation of the organic matter. Biological treatment encompasses basically aerobic and anaerobic treatment.

In most waste waters, the need for additional nutrient seldom appears, but in an aerobic operation, oxygen is essential for success operation of the systems. The most common aerobic processes are activated sludge and lagoon, active or trickling filters, and rotating contactors.

In contrast, anaerobic treatment proceeds with breakdown of the organic load to gaseous products that constitute most of the reaction products and biomass. Anaerobic treatment is the result of several reactions; the organic load present in the waste water is first converted to soluble organic material which in turn is consumed by acid producing bacteria to give volatile fatty acids and carbon dioxide and hydrogen. Further more anaerobic processes are also sensitive to temperature (Sawyer *et al*., 2003).

In general, when comparing a conventional aerobic treatment with anaerobic treatment systems the advantages of anaerobic systems are (Lema *et al*., 2001):

i. Lower treatment costs and production energy
ii. High flexibility, since it can be applied to very different types of effluents
iii. High organic loading rate operation
iv. Smaller volumes of excess sludge
v. Anaerobic organisms can be preserved for a long time, which make it possible to treat waste water that are generated with longer pauses in between

1.5.4 Combined method

Individual approach in reducing COD level show high tolerance but the combination technique would give better performances. Commonly applied treatment methods for COD removal from textile wastewater consisted of integrated processes involving various combinations of biological, physical, and chemical methods (.Azbar *et al*., 2004).

A rapid combined method of physical-chemical method has been developed for the determination of COD. The method involved removal by flocculation and precipitation of colloidal matter that normally passes through membrane filters.

For example study by Lin *et al*., 1996, indicated that the combined chemical treatment methods are very effective and are capable of elevating the water quality of the treated waste effluent to the reuse standard of the textile industry. While study by Ghoreishi *et al*., 2003 indicated that combined chemical-biological method showed higher efficiency and lower cost for the new technique of COD reduction. But generally, these integrated treatment methods are efficient but not cost effective (Azbar *et al*., 2004).

1.6 COD reduction by biological treatment

Treatment of the textile waste water via biological methods can be achieved by three approaches, involving fungi, algae, and bacteria. Although the biological treatment of waste water is important, it cannot completely remove soluble components, such as endocrine disrupters and pesticides (Ilyin *et al*., 2004).

1.6.1 Biological treatment by fungi

Waste water from textile industries constitutes a threat to the environment in large parts of the world. The degradation products of textile dye are often carcinogenic (Azbar *et al*., 2004). A key feature in the degradation processes involves generation of activated oxygen forms that can carry out the initial attack on the stable structure. Wood rotting fungi have interesting properties in the sense they are capable to degrade lignin which is polymeric structure with a lot of aromatic rings (Nilsson *et al*., 2006).

An advantage with these organisms is that they produce and excrete ligninolytic enzymes that are non-specific with regards to aromatic structure. This means that they are capable of degrading mixtures of aromatic compounds (Axelsson *et al*., 2006). The application of white-rot fungi in large scale waste treatment, however, has been impeded owing to the lack of appropriate reactor systems capable of coping with rather slow fungal degradation, loss of extra cellular enzymes and mediators with discharged water, and excessive growth of fungi (Faisal *et al*., 2006). Also, the fungi need to be supplied with an external carbon source in order to be able to degrade polycyclic aromatic hydrocarbons (Nilsson *et al*., 2006).

Besides white-rot fungi, obligate and facultative marine fungi occurring in coastal marine environments can be an important source for use in bioremediation of saline soil and waste water. The decolorization of colored effluents by lignin-degrading fungus isolated from sea grass detritus have been reported (D'Sauze *et al*., 2006).

1.6.2 Biological treatment by algae

The most rapid and extensive degradation of lignin caused by certain fungi, particularly white-rot fungi occurs in highly aerobic environments. However the high glucose requirement of the microorganisms appears to be the major drawback of fungal treatment. Therefore algae have been suggested to replace fungi to remove colour and AOX from textile waste (Tarlan *et al*., 2002).

Algae are microscopic, photosynthetic organisms which typically inhabit aquatic environments, soil, and other exposed locations (Mohan *et al*., 2002). Algal action was reported to represent a natural pathway for the conversion of lignin to other materials within the carbon cycle (Tarlan *et al*., 2002).

The potential of commonly available green algae belonging to species Spirogyra was investigated as viable biomaterials for biological treatment of simulated synthetic azo dye (reactive Yellow 22) effluents. The ability of the species in removing colour was dependent both on the dye concentration and algal biomass (Mohan *et al*., 2002). Green algae belonging to Chlorella and diatom species have also been reported being applied in textile effluent treatment (Tarlan *et al*., 2002).

1.6.3 Biological treatment by bacteria

The waste water management strategy for the future should meet the benefits of humanity safety, respect principles of ecology, and compatibility with other habitability systems (Ilyin *et al*., 2004). For these purpose the waste water management technologies, relevant to application of the biodegradation properties of bacteria are of great interest. The selection of bacterial species for the biological treatment depends upon the chemical composition of the dye and the alkalis and salts used in the dyeing methods (Babu *et al*., 2000).

Escherichia coli is a common bacteria found in the environment has been used for treating textile effluent. These bacteria grow very fast and double after every 20 minutes under favorable conditions of pH in the range of 6 to 8 and optimal temperature at 35^{o}C. COD reduction by these bacteria has achieved more than 60% removal (Babu *et al*., 2000).

1.7 Bacteria

1.7.1 *Acinetobacter baumanni* and *Acinetobacter calcoaceticus*

The genus *Acinetobacter* has undergone numerous taxonomic changes over the years and currently comprises at least 23 genospecies of clinical interest, of which only nine (*Acinetobacter calcoaceticus*, *Acinetobacter baumannii*, *A. haemolyticus*, *A. junii*, *A. lwoffii*, *A. radioresistens*, *A. schlinderi*, and *A. ursingii*) have been given a name (Krawczyk *et al*., 2002). The bacteria used in this study are *Acinetobacter calcoaceticus genospecies* 3 and *Acinetobacter calcoaceticus* have been isolated from textile waste.

Acinetobacter calcoaceticus genospecies 3 can be found in soil, water, sewage and in hospital environments such as respiratory and urinary drainage equipment, disinfectants and body fluids. It was formerly known as *Achromobacter anitratus* (Pal *et al*., 1981). *A.cakcoaceticus* is a non-motile, coccobacillary, strictly aerobic and Gram negative bacteria. It uses a variety of carbon sources for growth and can be cultured relatively on simple media including tripticase soya agar and nutrient agar. The optimum temperature for growth is at 30 ^{o}C (Bergogni-Berezin, 1995).

A. calcoaceticus is an opportunistic pathogen that has been reported to have caused serious and sometimes fatal infections. It can be recovered occasionally from human specimens such as urine. However, this pathogen appears to have little invasive power and depend upon a pre-existing break in the normal body defenses like a surgical wound to cause disease (Ana Isabel *et al*., 2004).

Clinical isolates associated with nosocomial outbreaks, particularly from respiratory infections, blood cultures, and wounds, are mostly identified *as Acinetobacter baumannii*. This genomic species alone is responsible for more than 80% of all Acinetobacter infections in the hospital environment. While the *Acinetobacter calcoaceticus* is considered mostly as an environmental species (Lagatolla *et al*., 1998).

A. baumannii is the second most common form of peritonitis caused by Gram negative bacteria. Along with other members of this genus, *A. baumannii* is known to harbor a variety of plasmid of different sizes, although most of them appear to be rather small about less than 23 kb (Dorcey *et al*., 1998).

1.7.2 *Cellulosimicrobium cellulans*

The third bacterium used in this study is *Cellulosimicrobium cellulans*, also known as *Cellulomonas cellulans*, *Oerkoviaxanthineolytica*, and *Arthrobacter luteus* (Pau Ferrer, 2005).

The species has undergone several taxonomic changes since its first description in 1923. It was first known as *Brevibacterium fermentans*, and two case reports have been published describing meningitis and sepsis due to this bacterium in infants and children. Some years later, *B. fermentans* was renamed *Oerskovia xanthineolytica*, and a few case reports were published on infections with *Oerskovia* spp., such as endocarditis, pyonephrosis, endophthalmitis, pneumonia, meningitis, parenteral nutrition-related septicemia, catheter-related septicemia, and peritonitis. The genera *Oerskovia* and *Cellulomonas* were united into the unique genus *Cellulomonas* in 1982, and *O. xanthineolytica* became *Cellulomonas cellulans*. Finally, in 2001, *Cellulomonas cellulans* was reclassified as *Cellulosimicrobium cellulans* (Beate Heym *et al*., 2005)

C.cellulans is a Gram positive rod shape bacteria and known as facultative anaerobic. It is size ranges from 0.9-5.0 mm. The optimal temperature for growth is at 30 ^{o}C. It is a Gram positive bacterium with the rod shape. After exhaustion of the medium, the rods transform into shorter rods or even spherical cells. *C.cellulans* is a non-motile and chemo-organotrophic bacterium (Schumann *et al*., 2001).

1.7.3 Mixed bacterial culture (consortium)

Although pure culture is reported to be effective in treating textile waste water, it is probable that a mixed culture or consortium would be more effective in degrading toxic compounds in textile waste water. A mixed culture can adapt better to changing conditions during growth. As an example, *Cellulosimicrobium cellulans* will dominate over *Acinetobacter calcoaceticus genospecie*s 3 and *Acinetobacter baumannii* due to its facultative anaerobic properties. Since *A*. *baumannii* and *A*. *calcoaceticus genospecie*s 3 are anaerobic bacteria, they require oxygen for growth. *C. cellulans* is a facultative anaerobic and it can survive both with and without oxygen supply.

The different conditions of textile waste water after certain times may affect the growth of the consortia. Thus, *Cellulosimicrobium cellulans* will predominate over the other two bacteria in a mixed culture when three organisms are used in treating textile waste water. Also under anaerobic consortia, reducing equivalents are formed by fermentative bacteria (dos Santos *et al*., 2006). Therefore, a consortium may be more effective in treating textile waste water.

1.8 Objective and scope of studies

The main objective of this research is to reduce the COD level of textile waste water using a biological method employing bacteria which was isolated from a local textile industry. The system used is a mixed culture or consortium consisted of three different bacteria, *Acinetobacter baumanni*, *Acinetobacter calcoaceticus genospecies* 3, and *Cellulosimicrobium cellulans.*

Studies on the ability of the individual and consortia adapting to the textile waste will be carried out. This is to obtain the tolerance level of the bacteria to the textile waste. Subsequently, studies on the ability of the consortium in reducing the COD level will be monitored using liquid cultures and freeze dried cultures. Finally, developed method will be compared with conventional COD reduction methods.

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