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MICROCLEAR: GREEN TECHNOLOGY FOR TREATING AND RECYCLING OF COLOURED WASTEWATER

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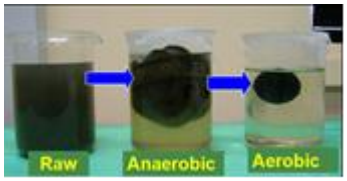
Graphical abstract



Abstract

The continuous growth and demand for our textiles and textile products have resulted in the generation of highly polluted and coloured wastewater emanating from the textile industries. These are detrimental to the environment and pose health threats to the human population if not properly treated. The treatment of colour is a great challenge over the last decades and until now, there is no single and economical treatment process. As effective treatment plant is generally expensive and unaffordable; a good alternative and timely solution is the utilisation of specialised group of microbes called *Microclear*. These microorganisms have the abilities to decolourise and transform coloured compounds into simpler and non-hazardous compounds without the use of chemicals. Intensive fundamental studies and also the application of the *Microclear* at the bench and pilot scale (sequential 1000 L and 2000 L) reactors to treat real wastewater were carried out. The microbes can also be applied directly into the existing treatment plant or ponding systems without the use of a commercial reactor. . Under the UTM-MTDC symbiosis program, Microclear Sdn. Bhd. was set up and work is in progress for large scale production of microbes to treat real textile wastewater in a demo plant of 150,000 L capacity located at the textile industry.

Keywords: *Microclear*, colour, textile wastewater, azo dyes

Abstrak

Pertumbuhan dan permintaan produk tekstil yang berterusan telah menyebabkan penghasilan air sisa yang sangat tercemar dan berwarna daripada industri tersebut. Ini memberi kesan yang buruk terhadap alam sekitar dan mengancam kesihatan manusia jika sisa-sisa tersebut tidak dirawat dengan sempurna. Rawatan warna adalah satu cabaran besar sejak beberapa dekad yang lalu. Sehingga kini, tiada proses rawatan yang menjimatkan. Loji rawatan yang berkesan pada umumnya adalah mahal dan tidak mampu diperolehi; kaedah alternatif yang bertepatan adalah penggunaan kumpulan khusus mikrob yang dinamakan *Microclear*. Mikroorganisma ini mempunyai kebolehan untuk menyahwarnakan dan mentransformasikan bahan berwarna kepada bahan ringkas dan tidak merbahaya serta tidak melibatkan penggunaan bahan kimia. Kajian asas yang intensif dan juga penggunaan *Microclear* dalam reaktor yang berskala makmal dan pilot (1000 L dan 2000 L) untuk merawat sisa air tekstil sebenar telah dijalankan. Kumpulan mikrob tersebut boleh digunakan terus ke dalam loji rawatan atau kolam yang sedia ada tanpa memerlukan reaktor komersial. Di bawah program simbiosis UTM-MTDC, Microclear Sdn. Bhd. telah ditubuhkan dan kerja-kerja yang sedang dijalankan merangkumi penghasilan mikrob berskala besar untuk tujuan merawat air sisa tekstil sebenar di sebuah fasiliti demo yang berkapasiti 150000 L di sebuah industri tekstil.

Kata kunci: *Microclear*, warna, sisa air tekstil, pewarna azo

1.0 INTRODUCTION

As effective treatment plant is generally expensive and unaffordable, the utilisation of a specialized group of microbes able to decolorize and transform coloured compounds in wastewater into simpler and non-hazardous compounds is a good alternative and timely solution. Now, with colour being included as a new water quality parameter in Environmental Regulations (Industrial Effluent), 2009, there is a great need for the related industries to find solutions to meet the environmental regulations. Wastewater discharge from industrial plants that produce coloured wastewater such as textile and apparel industries, food as well as printing industries need to be treated, prior to release into the environment. Sequential anaerobic–aerobic treatment process is viewed as a promising technology for the treatment of azo dye containing wastewater [1]. Under anaerobic or facultative anaerobic condition, the decolourisation process is often initiated by the transfer of electrons from reduced electron carriers via enzymatic reduction of azo bonds. This cleaves the dye's azo bonds (−N=N–), forming colourless yet hazardous aromatic amines [2, 3]. An aerobic process following the anaerobic treatment is required for mineralisation of the noxious aromatic amines via hydroxylation reaction involving a ring opening mechanism [1, 3].

The wastewaters contain dyes, dye breakdown products and other colorant materials that are toxic, non-degradable, or take longer time to degrade naturally, are detrimental to the environment and pose health threats to the human population if not properly treated. The pre-commercialisation project was secured from which funding of RM 2 million was allocated for developing scale up process for production of microbes. Microclear Sdn. Bhd. was also set up in 2012 to pave way for large scale production of microbes. The process parameters (10 L and 100 L bioreactors) were determined for subsequent larger scale production of microbes. Under the UTM-MTDC Symbiosis program, *Microclear* will be produced in large scale for the treatment of real textile wastewater.

The research challenge was to develop locally formulated group of microorganisms capable of removing colour from dye containing wastewater. These microorganisms are able to convert dye molecules which are generally considered as non-degradable or difficult organics into smaller and readily degradable molecules for safe discharge of effluent. Intensive fundamental studies using azo dyes as model dyes were carried out to understand how bacteria function to decolourise dyes under sequential facultative anaerobic condition and aerobic condition [4]. Utilising this group of bacteria offers an alternative GREEN solution to minimise the use of chemicals in conventional methods for treatment of coloured wastewater.

This paper reports on the selection and testing of bacteria capable of treating real textile wastewater. The production of microbes at the lab scale bioreactor and pilot scale bioreactor system will also be described.

2.0 EXPERIMENTAL

Microorganisms were isolated from different types of wastewater, activated sludge and food sources. The microorganisms were tested for their abilities to decolourise colourants mainly synthetic dyes and coloured wastewater and utilise dyes breakdown products as nutrients for growth. In addition, analyses were also carried out on water quality parameters to meet DOE compliance [5]. The selected bacteria were further applied for lab scale treatment process of real textile wastewater using shake flasks technique, lab scale bioreactor and pilot scale bioreactor system (sequential 2000 L and 1000 L bioreactors under sequential facultative anaerobic condition and aerobic condition, respectively). This pilot scale bioreactor system was placed on site at the biggest textile industries in Malaysia to study the performance of the microbes in treating real textile effluent (Bioremediation Process for Industrial Wastewater (03-01-01-001 BTK/ER/020).

3.0 RESULTS AND DISCUSSION

Intensive fundamental studies using azo dyes as model dyes were carried out to understand how bacteria function to decolourise dyes under sequential facultative anaerobic condition and aerobic condition [2]. Figure 1 shows the selected decolourising bacteria when examined under the Scanning Electron Microscope (SEM). Figure 2 shows the performance of *Microclear* bacteria used in the treatment of real wastewater in the pilot scale bioreactor Research was also carried out on the adaptation or acclimitisation of mixed culture of bacteria to utilize dyes in real wastewater as their major source of nutrients (carbon and nitrogen source). Nutrient requirements help explain how carbon and nitrogen sources influence the efficiency of the microbes in treating coloured wastewater.

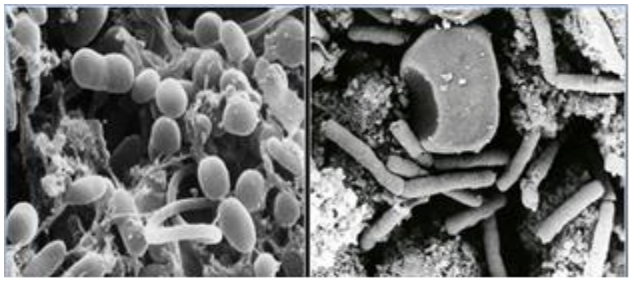


Figure 1 Mixed bacterial culture of *Microclear* examined under SEM (5000 X magnification)

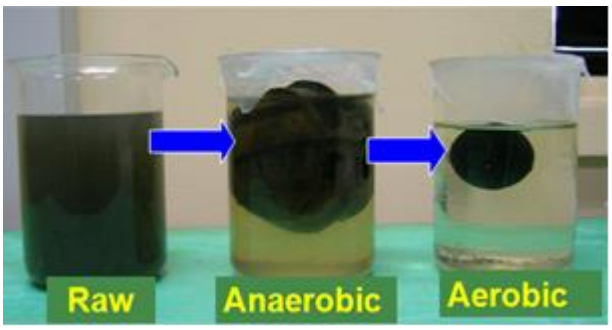


Figure 2 Treatment of raw textile wastewater using *Microclear*

Analyses of major compounds of degradation using the high performance liquid chromatography (HPLC) and Liquid chromatography-Mass spectrometer (LC-MS) methods were used to provide evidence for further conversion or transformation of decolourised effluents into readily degradable compounds that can be used as nutrients for growth of the microbes. The selected bacteria were further applied in lab scale treatment process of real textile wastewater involving shake flasks technique and lab scale bioreactor. Pilot scale bioreactor system (sequential 2000 L and 1000 L bioreactors) was placed on site at one of the biggest textile industries in Johor to study the performance of the microbes in treating real textile effluent [6]. Figure 3 shows the colour removal of textile wastewater was up to 93% of varying initial colour values of raw wastewater ranging between 200 – 900 ADMI units (dark blue line). The real wastewater was siphoned from the wastewater treatment plant and transferred into the facultative anaerobic reactor where slow mixing was provided. The reactors were filled inert support materials known as Cosmoballs for the immobilization of microorganisms. The black line graph represents colour values after the anaerobic process and it shows a good decrease of colour values between 150 – 220 ADMI. The pink line graph shows subsequent treatment of wastewater in aerobic reactor, which shows values of colour in the range of 30 - 60 ADMI. The total treatment gave very satisfactory colour removal with a change in colour from dark reddish to colourless effluent of less than 40 ADMI within two days.

Generally the Chemical Oxygen Demand (COD) of different batches of untreated raw textile wastewater were all above the permitted discharge values. The graph in Figure 4 shows the COD profile of textile wastewater before (raw) and after treatment (facultative anaerobic and aerobic) using *Microclear* over a period of 60 days. The COD of raw wastewater was represented by the blue line ranged from 200 to 1650 mg/L. Within two days, the COD values were reduced to less than 50 mg/L, meeting the discharge limit of standard A [7]. The pink line shows the COD values of anaerobic treatment ranging from 1700-80 mg/L. While the yellow line of

the graph refers to the COD values in the Aerobic Bioreactor showing a consistent decrease of COD values ranging from 160 to 10 mg/L. The acclimitised microbes were able to treat wastewater of varying initial values of colour and COD to meet environmental compliance [9].

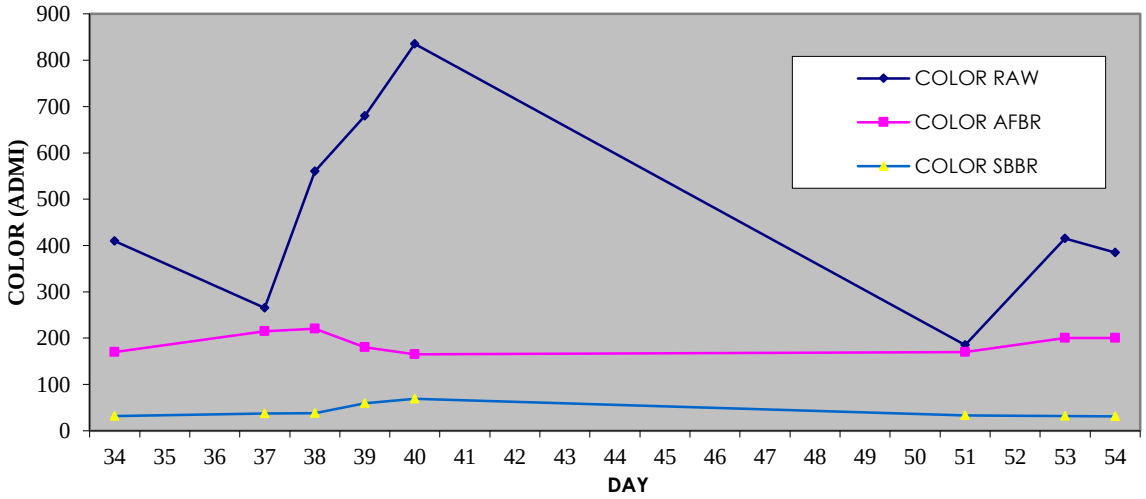


Figure 3 Profile of colour removal

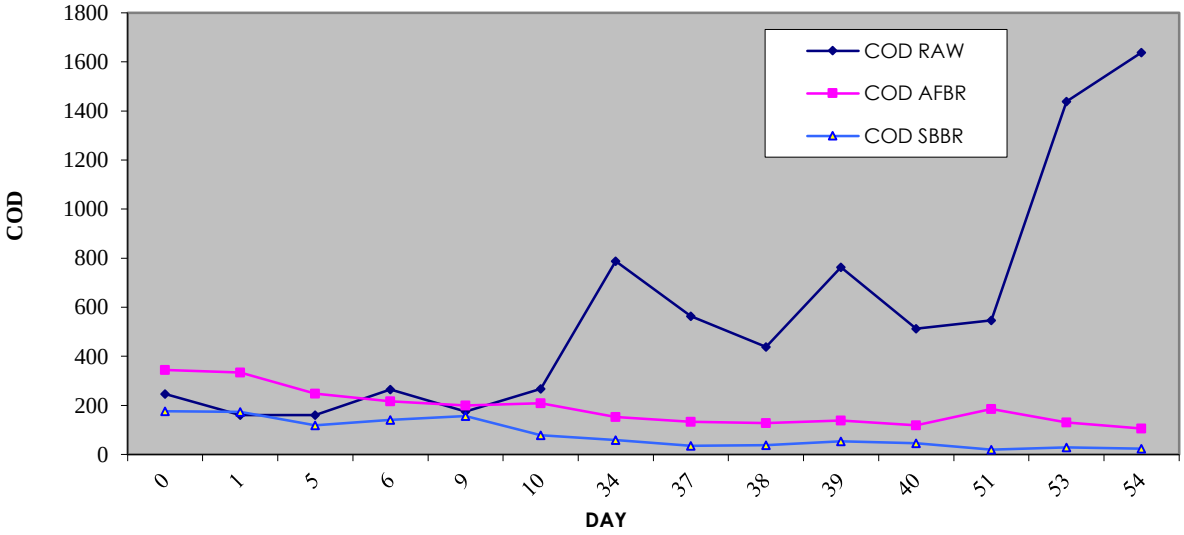


Figure 4 Profile of COD removal

Table 1 below shows overall best results obtained for the treatment of real wastewater using the pilot scale bioreactor, a sequential facultative anaerobic bioreactor (2000 L) and aerobic (1000 L) bioreactors.

Table 1 Average removal of effluent parameters and ecotoxicity test

COD	**98 %**
Colour	**92 %**
NH_3-N	**99 %**
TSS	**89 %**
EC_{50} (Daphnia magna)	**No value (not toxic to aquatic environment)**

4.0 CONCLUSION

In general, treatment of real textile wastewater using *Microclear* as the inoculum showed removal of COD, colour, ammoniacal nitrogen (NH3-N) and total suspended solids (TSS) of more than 90% meeting the discharge limit of standard A. Ecotoxicity tests of the treated wastewater with *Daphnia magna* also showed that the effluent was no longer toxic [8]. Work is in progress on the large scale production of microbes. Under the UTM-MTDC symbiosis programme, this project went through stringent procedures and training of personnels that led to the setting up of a company focusing on the production of microbes.

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