



**Scholars'
Press**

ECO

Basavaraju Manu
Sanjeev Chaudhari

**Sequential Anaerobic-aerobic
Treatment Of Azo Dye
Wastewater**

**Basavaraju Manu
Sanjeev Chaudhari**

Sequential Anaerobic-aerobic Treatment Of Azo Dye Wastewater

Scholar's Press

Impressum / Imprint

Bibliografische Information der Deutschen Nationalbibliothek: Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.d-nb.de> abrufbar.

Alle in diesem Buch genannten Marken und Produktnamen unterliegen warenzeichen-, marken- oder patentrechtlichem Schutz bzw. sind Warenzeichen oder eingetragene Warenzeichen der jeweiligen Inhaber. Die Wiedergabe von Marken, Produktnamen, Gebrauchsnamen, Handelsnamen, Warenbezeichnungen u.s.w. in diesem Werk berechtigt auch ohne besondere Kennzeichnung nicht zu der Annahme, dass solche Namen im Sinne der Warenzeichen- und Markenschutzgesetzgebung als frei zu betrachten wären und daher von jedermann benutzt werden dürften.

Bibliographic information published by the Deutsche Nationalbibliothek: The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Any brand names and product names mentioned in this book are subject to trademark, brand or patent protection and are trademarks or registered trademarks of their respective holders. The use of brand names, product names, common names, trade names, product descriptions etc. even without a particular marking in this works is in no way to be construed to mean that such names may be regarded as unrestricted in respect of trademark and brand protection legislation and could thus be used by anyone.

Coverbild / Cover image: www.ingimage.com

Verlag / Publisher:

Scholar's Press

ist ein Imprint der / is a trademark of

OmniScriptum GmbH & Co. KG

Heinrich-Böcking-Str. 6-8, 66121 Saarbrücken, Deutschland / Germany

Email: info@scholars-press.com

Herstellung: siehe letzte Seite /

Printed at: see last page

ISBN: 978-3-639-71166-0

Zugl. / Approved by: IIT Bombay, Ph.D. Thesis, 2006

Copyright © 2014 OmniScriptum GmbH & Co. KG

Alle Rechte vorbehalten. / All rights reserved. Saarbrücken 2014

**Basavaraju Manu
Sanjeev Chaudhari**

Sequential Anaerobic-aerobic Treatment Of Azo Dye Wastewater

CONTENTS

Contents	2
List of FIGURES	4
List of TABLES	5
Acronyms	6
Chapter 1 Introduction	7
1.1 Background and motivation	7
1.2 Objectives of the present study	10
1.3 Organisation of the thesis	11
Chapter 2 Literature Review	12
2.1 General	12
2.2 Azo dyes and intermediates	14
2.3 Sources of water pollution in a typical cotton textile industry	17
2.4 Overview of treatment options for the cotton textile industry wastewaters	19
2.4.1 Physico-chemical treatment methods and advanced oxidation processes (AOP)	20
2.4.2 Biological process for colour removal	20
2.5 Summary of the literature review	50
Chapter 3 Materials and Methods	53
3.1 Materials	53
3.2 Experimental set-up and procedure	56
3.2.1 Anaerobic treatment of selected azo dyes in semi-continuous mode under long hydraulic retention time (HRT)	56
3.2.2 Sequential anaerobic-aerobic treatment of synthetic azo dye solutions	57
1.1.4 Influent tanks	59
1.1.3 Aerobic reactors	59
1.1.2 Peristaltic pump	59
1.1.1 UASB Effluent Tanks	59
3.2.3 Batch anaerobic inhibition assay:	63
3.2.4 Adsorption studies of selected azo dyes on to anaerobic sludge	64
3.2.5 Decolourisation kinetics studies of the selected azo dye:	65
3.2.6 Identification of microbial cultures responsible for anaerobic decolourisation of azo dye and SEM analysis of UASB granular sludge.	65
3.2.7 Fenton's and hydrogen peroxide (H ₂ O ₂) treatment of azo dye solutions, UASB effluent and aerobic effluent	65
3.3 Analytical methods:	66
Chapter 4 Results and Discussion	68
4.1 Anaerobic treatment of azo dyes in semi-continuous mode	69
4.1.1 Decolourisation of AO7 dye	72
4.1.2 Decolourisation of RB8 dye	76
4.1.3 Decolourisation of RR141 dye	79

4.2	Batch anaerobic inhibition assay:	82
4.2.1	Total methanogenic activity	83
4.2.2	Maximum methanogenic activity	84
4.3	Anaerobic treatment of azo dyes in continuous mode by UASB reactors	86
4.3.1	Phase I: Start-up of the UASB reactors	87
4.3.2	Phase II: Sequential anaerobic-aerobic treatment at varying organic loading rate	95
4.3.3	Phase III: Effect of influent dye concentration, effect of alternate carbon source and redox mediator.	105
4.3.4	Phase IV: Attempts of revival of R1 and R3 reactors	114
4.3.5	Phase V: Fresh start-up of R1 and R3 reactors, influent dye concentration of 100 mg/L and effect of redox mediator on anaerobic decolourisation	119
4.4	Adsorption studies of selected azo dyes on to anaerobic sludge:	123
4.4.1	Preliminary assessment of adsorption of azo dyes on to anaerobic biomass	124
4.5	Decolourisation kinetics studies of the selected azo dyes	126
4.6	Identification of microbial cultures responsible for anaerobic decolourisation of azo dye and SEM analysis of anaerobic granular sludge samples	128
4.7	Hydrogen peroxide and Fenton's Treatment of influent dye solutions, anaerobic effluent and aerobic effluent	128
4.8	Depth-Wise analysis of aqueous phase parameters in various UASB reactors at different operational strategies during the study period	131
Chapter 5 Summary and Conclusions		135
5.1	Summary	135
5.2	Conclusions	136
5.3	Recommendations for future research	138
APPENDIX I		139
APPENDIX II		142
APPENDIX III		143
REFERENCES		147
ACKNOWLEDGEMENT		163

LIST OF FIGURES

Figure 2.1 Proposed mechanism of catalysis by azo reductase and NADPH	25
Figure 2.2 Proposed mechanism for reduction of azo dyes by whole bacterial cells [Pearce et al., 2003]	36
Figure 3.1 Chemical structures of the azo dyes used in the present study	55
Figure 3.2 Schematic of the sequential anaerobic-aerobic treatment scheme	59
Figure 4.1 Performance of the control reactor	71
Figure 4.2 Performance of the reactor treating AO7 dye	73
Figure 4.3 UV-Visible absorbance spectra for AO7 dye	74
Figure 4.4 Performance of the reactor treating RB8 dye	77
Figure 4.5 UV-Visible absorbance spectra for RB8 dye	78
Figure 4.6 Performance of the RR141 dye containing reactor	80
Figure 4.7 UV - Visible absorbance spectra for RR141 dye	81
Figure 4.8 Temporal variation of performance parameters during anaerobic treatment of AO7 dye (R1)	90
Figure 4.9 Temporal variation of performance parameters during anaerobic treatment of RR141 dye (R2)	92
Figure 4.10 Temporal variation of performance parameters during anaerobic treatment of RB8 dye (R3)	94
Figure 4.11 Temporal variation in performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	96
Figure 4.12 UV-Visible absorbance spectra of AO7 dye	97
Figure 4.13 Temporal variation of performance parameter during sequential anaerobic-aerobic treatment of RR141 dye (R3)	100
Figure 4.14 UV-Visible absorbance spectra of RR141 dye	101
Figure 4.15 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	103
Figure 4.16 UV-Visible absorbance spectra of RB8 dye	104
Figure 4.17 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	106
Figure 4.18 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RR141 dye (R2)	108
Figure 4.19 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RR141 dye (R2)	110
Figure 4.20 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	113
Figure 4.21 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	116
Figure 4.22 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	118
Figure 4.23 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	121
Figure 4.24 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	122

Figure 4.25 Plots of kinetics of colour removal (a) AO7, (b) RR141 and (c) RB8 dye	127
Figure 4.26 UV-Visible absorbance spectra for AO7 dye	129
Figure 4.27 Variation of aqueous phase parameters along the depth of R1, R2, R3 and R4	132
Figure 4.28 Variation of aqueous phase parameters along the depth of R1, R2, R3 and R4	133
Figure 4.29 Variation of aqueous phase parameters along the depth of R1, R2, R3 and R4	134
Figure A.1 FTIR spectrum of pure AO7 dye	139
Figure A.2 FTIR spectrum of AO7 anaerobic effluent dried powder	140
Figure A.3 FTIR Spectrum of pure Sulfanilic acid	141
Figure A.4 SEM Photographs of granules collected from control UASB reactor and UASB reactor fed with RR141 dye	142

LIST OF TABLES

Table 2.1 Major pollutant types in textile wastewater, their origin and relevance/impact on biological treatment (Delee <i>et al.</i> , 1998)	18
Table 2.2 Overview of various technologies for the treatment of textile effluents	19
Table 3.1 Important characteristics of the azo dyes used in this study	54
Table 3.2 Dyes present in different reactors and their influent characteristics	57
Table 3.3 List of the UASB reactor fed with the corresponding azo dye	58
Table 3.4 Operational conditions maintained during sequential anaerobic-aerobic treatment of selected azo dyes.	60
Table 4.1 Anaerobic inhibition assay results for AO7, RR141 and RB8 dye	86
Table 4.2 Colour removal efficiencies observed during adsorption studies of selected azo dyes on to anaerobic sludge	125
Table 4.3 Parameters of Freundlich isotherm for AO7, RR141 and RB8 dye	125
Table 4.4 Summary of colour removal efficiencies observed during sequential anaerobic-aerobic and hydrogen peroxide treatment of selected azo dyes under various operational conditions	130

SEQUENTIAL ANAEROBIC- AEROBIC TREATMENT OF AZO DYE WASTEWATER

The content of this book is part of the thesis submitted in partial fulfilment for the award of the degree of Ph.D. of the Indian Institute of Technology Bombay

CONTENTS

Contents	2
List of FIGURES	4
List of TABLES	5
Acronyms	6
Chapter 1 Introduction	7
1.1 Background and motivation	7
1.2 Objectives of the present study	10
1.3 Organisation of the thesis	11
Chapter 2 Literature Review	12
2.1 General	12
2.2 Azo dyes and intermediates	14
2.3 Sources of water pollution in a typical cotton textile industry	17
2.4 Overview of treatment options for the cotton textile industry wastewaters	19
2.4.1 Physico-chemical treatment methods and advanced oxidation processes (AOP)	20
2.4.2 Biological process for colour removal	20
2.5 Summary of the literature review	50
Chapter 3 Materials and Methods	53
3.1 Materials	53
3.2 Experimental set-up and procedure	56
3.2.1 Anaerobic treatment of selected azo dyes in semi-continuous mode under long hydraulic retention time (HRT)	56
3.2.2 Sequential anaerobic-aerobic treatment of synthetic azo dye solutions	57
1.1.4 Influent tanks	59
1.1.3 Aerobic reactors	59
1.1.2 Peristaltic pump	59
1.1.1 UASB Effluent Tanks	59
3.2.3 Batch anaerobic inhibition assay:	63
3.2.4 Adsorption studies of selected azo dyes on to anaerobic sludge	64
3.2.5 Decolourisation kinetics studies of the selected azo dye:	65
3.2.6 Identification of microbial cultures responsible for anaerobic decolourisation of azo dye and SEM analysis of UASB granular sludge.	65
3.2.7 Fenton's and hydrogen peroxide (H ₂ O ₂) treatment of azo dye solutions, UASB effluent and aerobic effluent	65
3.3 Analytical methods:	66
Chapter 4 Results and Discussion	68
4.1 Anaerobic treatment of azo dyes in semi-continuous mode	69
4.1.1 Decolourisation of AO7 dye	72
4.1.2 Decolourisation of RB8 dye	76
4.1.3 Decolourisation of RR141 dye	79

4.2	Batch anaerobic inhibition assay:	82
4.2.1	Total methanogenic activity	83
4.2.2	Maximum methanogenic activity	84
4.3	Anaerobic treatment of azo dyes in continuous mode by UASB reactors	86
4.3.1	Phase I: Start-up of the UASB reactors	87
4.3.2	Phase II: Sequential anaerobic-aerobic treatment at varying organic loading rate	95
4.3.3	Phase III: Effect of influent dye concentration, effect of alternate carbon source and redox mediator.	105
4.3.4	Phase IV: Attempts of revival of R1 and R3 reactors	114
4.3.5	Phase V: Fresh start-up of R1 and R3 reactors, influent dye concentration of 100 mg/L and effect of redox mediator on anaerobic decolourisation	119
4.4	Adsorption studies of selected azo dyes on to anaerobic sludge:	123
4.4.1	Preliminary assessment of adsorption of azo dyes on to anaerobic biomass	124
4.5	Decolourisation kinetics studies of the selected azo dyes	126
4.6	Identification of microbial cultures responsible for anaerobic decolourisation of azo dye and SEM analysis of anaerobic granular sludge samples	128
4.7	Hydrogen peroxide and Fenton's Treatment of influent dye solutions, anaerobic effluent and aerobic effluent	128
4.8	Depth-Wise analysis of aqueous phase parameters in various UASB reactors at different operational strategies during the study period	131
Chapter 5 Summary and Conclusions		135
5.1	Summary	135
5.2	Conclusions	136
5.3	Recommendations for future research	138
APPENDIX I		139
APPENDIX II		142
APPENDIX III		143
REFERENCES		147
ACKNOWLEDGEMENT		163

LIST OF FIGURES

Figure 2.1 Proposed mechanism of catalysis by azo reductase and NADPH	25
Figure 2.2 Proposed mechanism for reduction of azo dyes by whole bacterial cells [Pearce et al., 2003]	36
Figure 3.1 Chemical structures of the azo dyes used in the present study	55
Figure 3.2 Schematic of the sequential anaerobic-aerobic treatment scheme	59
Figure 4.1 Performance of the control reactor	71
Figure 4.2 Performance of the reactor treating AO7 dye	73
Figure 4.3 UV-Visible absorbance spectra for AO7 dye	74
Figure 4.4 Performance of the reactor treating RB8 dye	77
Figure 4.5 UV-Visible absorbance spectra for RB8 dye	78
Figure 4.6 Performance of the RR141 dye containing reactor	80
Figure 4.7 UV - Visible absorbance spectra for RR141 dye	81
Figure 4.8 Temporal variation of performance parameters during anaerobic treatment of AO7 dye (R1)	90
Figure 4.9 Temporal variation of performance parameters during anaerobic treatment of RR141 dye (R2)	92
Figure 4.10 Temporal variation of performance parameters during anaerobic treatment of RB8 dye (R3)	94
Figure 4.11 Temporal variation in performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	96
Figure 4.12 UV-Visible absorbance spectra of AO7 dye	97
Figure 4.13 Temporal variation of performance parameter during sequential anaerobic-aerobic treatment of RR141 dye (R3)	100
Figure 4.14 UV-Visible absorbance spectra of RR141 dye	101
Figure 4.15 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	103
Figure 4.16 UV-Visible absorbance spectra of RB8 dye	104
Figure 4.17 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	106
Figure 4.18 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RR141 dye (R2)	108
Figure 4.19 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RR141 dye (R2)	110
Figure 4.20 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	113
Figure 4.21 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	116
Figure 4.22 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	118
Figure 4.23 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of AO7 dye (R1)	121
Figure 4.24 Temporal variation of performance parameters during sequential anaerobic-aerobic treatment of RB8 dye (R3)	122

Figure 4.25 Plots of kinetics of colour removal (a) AO7, (b) RR141 and (c) RB8 dye	127
Figure 4.26 UV-Visible absorbance spectra for AO7 dye	129
Figure 4.27 Variation of aqueous phase parameters along the depth of R1, R2, R3 and R4	132
Figure 4.28 Variation of aqueous phase parameters along the depth of R1, R2, R3 and R4	133
Figure 4.29 Variation of aqueous phase parameters along the depth of R1, R2, R3 and R4	134
Figure A.1 FTIR spectrum of pure AO7 dye	139
Figure A.2 FTIR spectrum of AO7 anaerobic effluent dried powder	140
Figure A.3 FTIR Spectrum of pure Sulfanilic acid	141
Figure A.4 SEM Photographs of granules collected from control UASB reactor and UASB reactor fed with RR141 dye	142

LIST OF TABLES

Table 2.1 Major pollutant types in textile wastewater, their origin and relevance/impact on biological treatment (Delee <i>et al.</i> , 1998)	18
Table 2.2 Overview of various technologies for the treatment of textile effluents	19
Table 3.1 Important characteristics of the azo dyes used in this study	54
Table 3.2 Dyes present in different reactors and their influent characteristics	57
Table 3.3 List of the UASB reactor fed with the corresponding azo dye	58
Table 3.4 Operational conditions maintained during sequential anaerobic-aerobic treatment of selected azo dyes.	60
Table 4.1 Anaerobic inhibition assay results for AO7, RR141 and RB8 dye	86
Table 4.2 Colour removal efficiencies observed during adsorption studies of selected azo dyes on to anaerobic sludge	125
Table 4.3 Parameters of Freundlich isotherm for AO7, RR141 and RB8 dye	125
Table 4.4 Summary of colour removal efficiencies observed during sequential anaerobic-aerobic and hydrogen peroxide treatment of selected azo dyes under various operational conditions	130

ACRONYMS

ADMI	American dye manufacturing institute
AOP	Advanced oxidation processes
AQS	Anthraquinone -2-sulfonate
AQDS	Anthraquinone-2,6-disulfonate
COD	Chemical oxygen demand
CSTR	Completely stirred tank reactor
d	day(s)
DO	Dissolved oxygen
FAD	Flavinadeninenucleotide
FMN	Flavinmononucleotide
g	Gram(s)
GAC	Granular activated carbon
GDP	Gross development product
h	hours(s)
HRT	Hydraulic retention time
min	minute(s)
mL	milli liters
mV	milli volts
M	Molar
MLSS	Mixed liquor suspended solids
MLVSS	Mixed liquor volatile suspended solids
MMR	Maximum rate ratio
NAD	Nicotinamide adenine dinucleotide
NADPH	Nicotinamide adenine dinucleotide phosphate
nm	nanometer(s)
OLR	Organic loading rate
ORP	Oxidation-reduction potential
PAC	Powdered activated carbon
PVA	Polyvinyl alcohol
SBR	Sequencing batch reactor
SLR	Sludge loading rate
SRT	Sludge retention time
t	Time
TOC	Total organic carbon
TDS	Total dissolved solids
TMA	Total methanogenic activity
TS	Total solids
UASB	Upflow anaerobic sludge blanket
VSS	Volatile suspended solids

Chapter 1

Introduction

1.1 Background and motivation

Textile industry is the single largest foreign exchange earner for India. Currently it accounts for about 8 % of gross development product (GDP), 20 % of the industrial production and over 30 % of export earnings of India. About 38 million people are gainfully employed with the industry making it the second largest employment providing sector after agriculture (<http://www.icmfindia.com/industry/india/index.asp>).

Textile industry is classified into 3 main categories viz. cotton, polyester and manmade textile manufacturing. Among all the textile fibers cotton is widely used. There are more than 1000 textile mills mainly centered in Mumbai, Surat, Ahmedabad, Coimbatore, Delhi and Kanpur. The rivers such as Kulu near Mumbai, Ganga at Kanpur, Kali at Meerut (Uttar Pradesh), Hoogly near Calcutta, Cauvery (Tamil Nadu) and many more fresh water streams are

seriously polluted by these textile industrial effluents which include wastes like metals (Cu, Zn, Pb, Hg, Cr, Co) and other organic and microbial impurities. The main reason for this serious problem is that all these industries use the older conventional treatment technology consisting of chemical coagulation followed by activated sludge process, which makes them difficult to cope up with the change in the scenario of stringent new regulations on disposable limits which are improvised by the pollution control boards. Over the last five years several mills have closed or are on the verge of closure due to noncompliance with the state pollution control (Shailaja, 2005).

India has the largest cotton acreage in the world, and cotton is the dominant fibre in the Indian industry. Approximately 12.3 millions of 480 lb. bales of cotton were produced in India in the year 2000 and were around 14.1% of the total world production of cotton (<http://www.icmfIndia.com/industry/india/index.asp>). Azo dyes are extensively used for dyeing of cotton. They comprise about 60-70% of the total dyes produced, i.e. around 26,000 in number and hence the largest group of synthetic colorants known (Mohan *et al.*, 2002). They are characterized by their typical nitrogen to nitrogen ($-N=N-$) bonds, which is highly electron deficient in nature. Due to the poor exhaustion properties of azo dyes as much as 40% of the initial dye applied remains unfixed and end up in effluents (Shah, 1998). As a consequence, they are the most common group of synthetic colorants released into the environment. They are synthetic in nature, have complex chemical structures, alien to the natural biotic environment and hence persist in nature. Azo dyes, on reductive cleavage of one or more azo groups form aromatic amine, which are generally, acknowledged being an animal carcinogen. Various experiments conducted on animals revealed the potential of azo compounds to cause cancer and reported to be carcinogens for human beings also. Among all types of dyes investigated, the toxicity of azo dyes on the *Bacillus cereus* and *Escherichia coli* cultures was found to be prominent.

Several countries due to its potential toxic nature have banned the use of azo dyes. Rao and Reddy (1996) have reported that dye had altered considerable physical and engineering properties of the soil. About 1000 mg/l of dye is present in a typical dyebath (Ince and Tezcanli, 1999). About 40-65 liters of wastewater is generated per kg of cloth produced. Dyeing, desizing and scouring processes are the major sources of water pollution in a textile industry. Apart from the aesthetic deterioration of the natural water bodies, they also cause harm to the flora and fauna in the natural environment. Rao *et al.* (1993) observed that the

toxic nature of dye effluents cause death of soil microorganisms which may effect agricultural productivity. Some of the rare species of flora and fauna in the catchment area where dye effluents are discharged in Rajasthan state (India) was eliminated and also the vegetative cover of the catchment area is considerably reduced (Mohan *et al.*, 2002). Hence, it becomes imperative that dye is to be removed from the effluents before it is disposed off.

Wastewaters from a textile industry are complex waste products containing dyes, sizing agents, and dyeing aids that are characterised by their deep colour and high concentrations of environmental pollutants. Generally effluent is characterized by pH: 9.8-11, COD: 1300-2000 mg/l, TS: 4900-7000 mg/l and colour: 1500-4500 ADMI units (Neelima and Dilip, 1998). Colour and COD are the two parameters of importance and are to be taken care of in case of textile wastewaters. COD is mainly due to the usage of sizing agents like starch, polyvinyl alcohol etc. Colour is due to the use of dyes, pigments and pastes in dyeing and printing of yarns and fabrics.

Various physicochemical, advanced oxidation processes, biological processes and usually a combination of aforementioned treatment technologies are adopted to treat textile wastewaters to achieve the discharge limits and disposed off. In the past mainly chemical coagulation followed by Activated sludge process was adopted to treat the textile wastewaters. However azo dyes due to their hydrophilic nature and present in hydrolyzed conditions in wastewaters could not be removed by this technique. In general physicochemical methods and advanced oxidation processes are costly. Biological processes are cheaper than the others in investment and operation costs. Investment costs for biological processes range from 5 to 20 times less than chemical ones such as ozone or hydrogen peroxide. Meanwhile treatment costs range from 3 to 10 times less (Mario *et al.*, 1997).

Colour removal using pure cultures (algal, fungal and bacterial) is impractical, because to maintain them in the pure form on a large scale and actual field conditions is quite difficult. Due to the electron withdrawing nature of the azo dyes/ bonds they are not susceptible to oxidative catabolism (Knackmuss, 1996). However under anaerobic conditions, decolourisation of azo dyes and reactive dyes can be easily achieved (Carliell *et al.*, 1995). During anaerobic metabolism, in the presence of a labile carbon source, the azo bond is gratuitously broken, thus rendering the dye colourless, with the formation of corresponding aromatic amines. The aromatic amines thus formed are toxic to the anaerobic biomass, but