

PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

UNIVERSITY OF CONSTANTINE 3



FACULTY OF PROCESS ENGINEERING
CHEMICAL ENGINEERING DEPARTMENT

N°d'ordre:..., ..., ..., ...

Série :... .., .., .., ...

Master's Dissertation

Field: Process engineering

Option: Chemical Engineering

**Residence time distribution in a solar reactor on a pilot scale:
Application to the treatment of organic pollutants in a continuous
system by UV/chlorine**

Submitted by:

Merazka Rania

Laroui Kenza

Laib Mohamed Islem

Supervised by

Dr. Bouchareb Mohammed

Kheir-Eddine

Academic Year: 2023/2024

June session

LIST OF CONTENTS

List of contents

List of figures

List of tables

List of Abbreviations

List of notations

General Introduction 1

Chapter I: Bibliographic Review

I.1. Introduction.....	Error! Bookmark not defined.
I.1.1. Dye's definition.....	Error! Bookmark not defined.
I.1.2. Environmental impact.....	Error! Bookmark not defined.
I.1.3. Dyes degradation and discoloration.....	Error! Bookmark not defined.
I.2. Advanced Oxidation Processes.....	Error! Bookmark not defined.
I.2.1. AOP's definition.....	Error! Bookmark not defined.
I.2.2. Purpose of Advanced Oxidation Processes.....	Error! Bookmark not defined.
I.2.3. Description of hydroxyl radical OH•.....	Error! Bookmark not defined.
I.2.4 Types of Advanced Oxidation Processes.....	Error! Bookmark not defined.
A. Photocatalysis.....	Error! Bookmark not defined.
B. Ozonation.....	Error! Bookmark not defined.
C. Fenton Process Fe ⁺² /H ₂ O ₂	Error! Bookmark not defined.
D. UV/H ₂ O ₂	Error! Bookmark not defined.
E. Hydroxyl Radical-Based AOPs.....	Error! Bookmark not defined.
I.2.5. Mechanisms of Advanced Oxidation Processes.....	Error! Bookmark not defined.
I.2.5.1 Generation of Reactive Oxygen Species.....	Error! Bookmark not defined.
I.2.5.2. Reaction Pathways.....	Error! Bookmark not defined.
I.2.6. Applications of Advanced Oxidation Processes.....	Error! Bookmark not defined.
I.2.7. Advantages of Advanced Oxidation Processes.....	Error! Bookmark not defined.
I.2.8. Limitations and Challenges.....	Error! Bookmark not defined.
I.2.9. Parameters affecting AOPs.....	Error! Bookmark not defined.
I.2.9.1. Light intensity, wavelength, and irradiation time.....	Error! Bookmark not defined.
I.2.9.2. Effect of the initial concentration of dye.....	Error! Bookmark not defined.
I.2.9.3. Effect of the dose of semiconductor.....	Error! Bookmark not defined.
I.2.9.4. Effect of pH.....	Error! Bookmark not defined.
I.2.9.5. Effect of temperature.....	Error! Bookmark not defined.
I.2.9.6. Particle size and crystallinity.....	Error! Bookmark not defined.

LIST OF CONTENTS

I.3. Photocatalytic reactors	Error! Bookmark not defined.
I.3.1. Solar photocatalytic reactors	Error! Bookmark not defined.
I.3.1.1 Parabolic trough reactors	Error! Bookmark not defined.
I.3.1.2. Non-concentrating reactors	Error! Bookmark not defined.
I.3.1.3. Compound Parabolic Collectors (CPCs)	Error! Bookmark not defined.
I.3.2. Artificial light reactor.....	Error! Bookmark not defined.
I.3.2.1. Radial irradiation reactors	Error! Bookmark not defined.
I.3.2.2. External irradiation reactors.....	Error! Bookmark not defined.
I.3.3. Applications of photocatalytic reactors.....	Error! Bookmark not defined.
I.4.Hypochlorite Sodium	Error! Bookmark not defined.
I.4.1. Definition and properties	Error! Bookmark not defined.

Chapter II: Materials and Methods

II.1. Introduction	Error! Bookmark not defined.
II.2. Materials and equipment's.....	Error! Bookmark not defined.
II.2.1. Materials	Error! Bookmark not defined.
II.2.2. Equipment's	Error! Bookmark not defined.
II.2.2.1. Balance	Error! Bookmark not defined.
II.2.2.2. PH meter	Error! Bookmark not defined.
II.2.2.3. Magnetic Agitator.....	Error! Bookmark not defined.
II.2.2.4. Radiometer.....	Error! Bookmark not defined.
II.2.2.5. Spectrophotometer.....	Error! Bookmark not defined.
II.3. Chemicals used	Error! Bookmark not defined.
II.3.1. Basic Blue 41 dye (BB41)	Error! Bookmark not defined.
II.3.2. Sulfuric acid.....	Error! Bookmark not defined.
II.3.3. Sodium Hydroxide (NaOH).....	Error! Bookmark not defined.
II.3.4. Basic Red dye 46	Error! Bookmark not defined.
II.3.5. Sodium Hypochlorite (NaClO).....	Error! Bookmark not defined.
II.4. Experimental set-up.....	Error! Bookmark not defined.
II.4.1. Solar photocatlytic reactor (CPC).....	Error! Bookmark not defined.
II.4.2.The photocatalytic reactor with artificial light	Error! Bookmark not defined.
II.6. Experimental protocol	Error! Bookmark not defined.
II.6.1. Preparation of chloride solution	Error! Bookmark not defined.
II.6.2. Preparation of NaClO solutions.....	Error! Bookmark not defined.

LIST OF CONTENTS

II.6.3. preparation of dye solutions and startup of the process.....	Error! Bookmark not defined.
II.7. Methods of analysis	Error! Bookmark not defined.
II.7.1. UV/Visible Spectrophotometry	Error! Bookmark not defined.
II.7.1.1. Establishment of the calibration curve	Error! Bookmark not defined.
II.7.2. PH measurement.....	Error! Bookmark not defined.
II.7.3. Residence Time Distribution “RTD”	Error! Bookmark not defined.
II.7.3.1. Residence time and residence time distribution	Error! Bookmark not defined.
II.7.3.2. Plug flow reactor PFR	Error! Bookmark not defined.
II.7.3.3. Continuous stirred tank reactors CSTR	Error! Bookmark not defined.
II.7.3.4. Experimental determination of the residence time distribution (RTD)	Error! Bookmark not defined.
II.7.3.5. Associated parameters to the RTD	Error! Bookmark not defined.
II.8.5. Design of experiments using Box-Behnken Design..	Error! Bookmark not defined.
II.8.5.1. Fundamentals	Error! Bookmark not defined.
II.8.5.2. Key Characteristics of Box-Behnken Design	Error! Bookmark not defined.
II.8.5.3. Applications of Box-Behnken Design	Error! Bookmark not defined.
II.8.5.4. Schemes for Implementing Box-Behnken Design	Error! Bookmark not defined.

Chapter III: Results and Discussion

III.1. Introduction	Error! Bookmark not defined.
III.2. Results and discussion.....	Error! Bookmark not defined.
III.2.1. Experimental Conditions of the residence time distribution (RTD).....	Error! Bookmark not defined.
III.3. Batch system	Error! Bookmark not defined.
III.4.1. Influence of chlorine concentration.....	Error! Bookmark not defined.
III.4.2. Effect of UV radiation	Error! Bookmark not defined.
III.4.4. Effect of Temperature	Error! Bookmark not defined.
III.4.5. Effect of dye flow rate	Error! Bookmark not defined.
III.4.6. Effect of chlorine flow rate	Error! Bookmark not defined.
III.4.6. Effect of pH	Error! Bookmark not defined.
III.5. Interaction between dye flow rate, chlorine concentration and chlorine flow rate ..	Error! Bookmark not defined.
III.5.1. Evaluation of the model quality by the coefficient of determination R^2	Error! Bookmark not defined.

LIST OF CONTENTS

III.5.3. Interaction between dye flow rate and chlorine flow rate	Error! Bookmark not defined.
III.5.4. Interaction between dye flow rate and chlorine concentration	Error! Bookmark not defined.
III.6. Optimal conditions for BB41 degradation by Solaire UV/Chlorine with continuous mode	Error! Bookmark not defined.
General Conclusion	73

Abstract

In our experiments we conducted the study of the residence time distribution in order to understand the hydrodynamics of a solar reactor type CPC by applying the advanced oxidation processes for the treatment of organic pollutants; BB41 in continuous system by sodium hypochlorite NaClO without and with exposure to sunlight.

Sodium hypochlorite (NaClO) exhibited superior photocatalytic degradation efficiency for BB41 dye under solar irradiation.

The UV/NaClO process proved to be highly effective for BB41 dye degradation in a solar reactor.

The experimental design method was applied to solar reactor results, which saves our time and analyzes results and studies the effect of chlorine concentration, BB41 concentration, chlorine flow rate and other factors in several conditions.

From the previous studies, the optimum values for achieving a 81.55% of conversion rate: are: 40 l/h for the chlorine flow rate, 6 mm for chlorine concentration, 300l/h for the dye flow rate, a PH of 8.1 and a temperature of 25°C.

Key words

Wastewater treatment; dyes; Photoreactors; Advanced oxidation process; step injection
Residence time distribution.

المخلص

في تجاربنا، أجرينا دراسة لفهم الديناميكا الهيدرولوجية لمفاعل شمسي من نوع CPC عن طريق تطبيق عمليات الأكسدة المتقدمة لمعالجة الملوثات العضوية، وتحديدًا للصبغة BB41، في نظام مستمر باستخدام هيبوكلوريت الصوديوم NaClO دون تعرض لأشعة الشمس ومعها. أظهرت هيبوكلوريت الصوديوم (NaClO) فعالية متفوقة في تحلل الصبغة BB41 تحت تأثير الشمس، وكذلك أثبتت عملية الأشعة فوق البنفسجية/NaClO فعاليتها العالية في تحلل الصبغة BB41 في المفاعل الشمسي.

تم تطبيق طريقة التصميم التجريبي على نتائج المفاعلات الشمسية، والتي توفر الوقت وتساعد في تحليل النتائج ودراسة تأثير تركيز الكلور والصبغة BB41 ومعدل تدفق الكلور وعوامل أخرى في ظروف متعددة.

القيم الأمثل لتحقيق معدل تحويل بنسبة 81.55% هي: 40 لتر/ساعة لمعدل تدفق الكلور، 6 ملم لتركيز الكلور، 300 لتر/ساعة لمعدل تدفق الصبغة درجة الحموضة 8.1 ودرجة الحرارة 25°C

الكلمات المفتاحية

معالجة مياه الصرف الصحي. الاصبغ. المفاعلات الضوئية عملية الاكسدة المتقدمة. توزيع وقت الإقامة.

Résumé

Dans nos expériences, nous avons étudié la distribution des temps de séjour afin de comprendre l'hydrodynamique d'un réacteur solaire de type CPC, en appliquant des processus d'oxydation avancés pour le traitement des polluants organiques ; BB41 dans un système continu avec du hypochlorite de sodium NaClO, avec et sans exposition au soleil.

Le hypochlorite de sodium (NaClO) a montré une efficacité de dégradation photocatalytique supérieure pour le colorant BB41 sous l'irradiation solaire.

Le processus UV/NaClO s'est avéré très efficace pour la dégradation du colorant BB41 dans un réacteur solaire.

La méthode de conception expérimentale a été appliquée aux résultats du réacteur solaire, ce qui permet d'économiser du temps et d'analyser les résultats ainsi que d'étudier l'effet de la concentration de chlore, de la concentration de BB41, du débit de chlore et d'autres facteurs dans plusieurs conditions.

D'après les études précédentes, les valeurs optimales permettant d'atteindre un taux de conversion de 81,55 % sont les suivantes : un débit de chlore de 40 l/h, une concentration de chlore de 6 mm, un débit de colorant de 300 l/h, un pH de 8,1 et une température de 25 °C.