UNIVERSITI PUTRA MALAYSIA

KINETICS AND MECHANISM OF AMMONIUM ION ADSORPTION USING NATURAL ZEOLITE - MORDENITE

NORMALA BT HALIMOON

FSMB 2001 32

KINETICS AND MECHANISM OF AMMONIUM ION ADSORPTION USING NATURAL ZEOLITE - MORDENITE

By

NORMALA BT HALIMOON

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Food Science and Biotechnology University Putra Malaysia

February 2001

DEDICATION

Bismillahirrahmannirahim,

Alhamdullillah.

Specially dedicated to:

- *My Supervisor @ Prof. Dr. Mohamed Ismail Bin Abdul Karim*
- *My Committee Members @ Prof. Madya Dr. Azlzkariya Bin Ariff*
  @ Prof. Madya Dr. Mohd Ali Bin Hassan
- *My father @ Halimoon Bin Hamid*
- *My mother @ Rahamah Bt Mohd*
- *All my siblings*
- *All my friend*
- *And My special friend @ Khairul Husni Kamaruddin*

Thanks for your loving support during the difficult time.

Amin.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

KINETICS AND MECHANISM OF AMMONIUM ION ADSORPTION USING NATURAL ZEOLITE- MORDENITE

By

NORMALA BT HALIMOON

February 2001

Chairman: Professor Dr. Mohamed Ismail Bin Abdul Karim

Faculty: Food Science and Biotechnology

Mordenite, one of the natural zeolites, has the capacity to remove ammonium ion from wastewaters through adsorption phenomenon. This study is a preliminary work of using mordenite to remove ammonium in effluent for tertiary treatment. The feasibility of using mordenite to remove ammonium ion in aqueous solution was carried out using shake flask, stirred tank batch reactor and packed-bed column experiments. The effect of mordenite particle size, ammonium concentration, mordenite concentration, pH, temperature and degree of agitation on the efficiency of adsorption were investigated. The kinetics of ammonium ion sorption was determined using Langmuir and Scatchard sorption isotherm models. The mechanism of ammonium adsorption was investigated using FTIR and electron microscope.

In shake flask experiment under equilibrium conditions, the efficiency of ammonium ion removal was optimum at resident time of 6 hours, for granules of

75 μm size, in water containing less than 6 mg/L ammonium ion, in mordenite concentration of 3 g/L, at room temperature, with agitation of 200 rpm and near neutral initial pH (6.5-7.5). Ammonium ion removal of 94% (2.49 mg/g uptake) was achieved when 50 g/L mordenite was used to remove 100 mg/L ammonium concentration under optimum conditions. The sorption isotherm kinetic data of ammonium ion by mordenite fitted well to Langmuir model but did not fit well to Scatchard plot. SEM and FTIR data indicated that ammonium ion was adsorbed on the mordenite particle. When 2 L stirred tank reactor was used as a contactor, the ammonium uptake capacity ranging from 85-96% was obtained at agitation speed of 200 rpm, concentration of mordenite of 2.67 g/L and 6 mg/L ammonium concentration. Absolute removal of ammonium from solution was achieved when fixed packed-bed column was used as a contactor at low flowrate (2 mL/min) and increased weight of mordenite in the column (48 g), which show less than 5 mg/L ammonium in the effluent before breakthrough was achieved when 100 mg/L ammonium concentration was used. Desorption experiments showed that 37% ammonium recovery in the shake flask and 80-98% in the column contactor. From the study, the result indicated that mordenite has a potential to be promoted as adsorbent that could be used to removed ammonium from solution and can be apply for wastewater treatment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan Ijazah Master Sains

KINETIK DAN MEKANISMA PENJERAPAN ION AMMONIUM OLEH ZEOLITE SEMULAJADI- MORDENITE

Oleh

NORMALA BT HALIMOON

Februari 2001

Pengerusi : Profesor Dr. Mohamed Ismail Bin Abdul Karim

Fakulti : Sains Makanan dan Bioteknologi

Mordenite adalah satu daripada zeolite semulajadi yang mempunyai keupayaan untuk memindahkan ion ammonium dari air sisa secara penjerapan. Kajian ini adalah asas untuk memindahkan ammonium menggunakan mordenite dalam merawat air sisa peringkat ketiga. Kebolehan mordenite memindahkan ion ammonium dalam larutan akuas telah dijalankan dalam kelalang pengoncang, reaktor pengaduk dan turus 'packed-bed'. Kesan kecekapan penjerapan telah dijalankan ke atas saiz partikal, kepekatan ammonium, kepekatan mordenite, pH larutan, suhu dan darjah pengacauan pada keseimbangan. Kinetik jerapan ion ammonium ditentukan menggunakan model isotherma jerapan seperti Langmuir dan Scatchard. Manakala mekanisma penjerapan ditentukan menggunakan FTIR dan mikroskop elektron.

Dalam ujikaji kelalang penggoncang pada keseimbangan, kecekapan penjerapan adalah optima pada masa 6 jam, partikal size 75 μm, kepekatan ion ammonium <6 mg/L, kepekatan mordenite 3 g/L, pada suhu bilik 30°C,

pengacauan 200 rpm dan pH awal hampir natural (6.5-7.5). Pemindahan ion ammonium mencapai 94% (2.49 mg/g) menggunakan 50 g/L mordenite untuk memindahkan 100 mg/L ammonium pada keadaan optima. Data kinetik penjerapan isoterma ion ammonium oleh mordenite dari ujikaji menepati model Langmuir tetapi tidak menepati model Scatchard. Data SEM dan FtiR menunjukkan ammonium terjerap di atas partikal mordenite. Apabila tangki pengaduk 2 L digunakan sebagai kontaktor, pengambilan ammonium paling baik dalam julat 85-96% diperolehi pada kelajuan pengacauan 200 rpm, kepekatan mordenite 2.67 g/L dan kepekatan ammonium 6 mg/L. Pemindahan ammonium dalam larutan paling berkesan dicapai apabila turus 'packed bed' digunakan sebagai kontaktor pada kadar alir yang rendah (2 mL/min) dan pada berat mordenite yang paling tinggi dalam turus (48 g), yang menunjukkan kurang daripada 5 mg/L ammonium dalam larutan akhir sebelum 'breakthrough' dicapai pada kepekatan awal 100 mg/L. Ujikaji nyah-jerapan menunjukkan 37% ammonium diperolehi dalam kelalang penggoncang dan 80-98% dalam turus. Dari ujikaji ini, menunjukkan mordenite berpotensi sebagai bahan penjerap untuk memindahkan ammonium dalam larutan dan boleh diagihkan untuk merawat air sisa.

ACKNOWLEDGEMENTS

Bismillahirrahmannirahim,

Firstly I would like to express my sincere appreciation and thanks to my chairman, Prof. Dr. Mohamed Ismail Bin Abdul Karim and members of supervisory committee Assoc. Prof. Dr Arbakariya Bin Ariff and Assoc. Prof. Dr. Mohd Ali Bin Hassan for their suggestions, advice, support and guidance throughout my study.

I give thanks to merciful Allah for giving me the strengths to complete this study. My appreciation and gratitude go to my father, Haji Halimoon Bin Hamid and my mother, Hajjah Rahamah Bt Mohd for their constant support, love and for being so patient throughout my graduate study. My heartfelt thanks to Khairul Husni bin Kamaruddin (Abg) for his supports, wonderful patience and care. Thank you very much.

Sincere thanks and gratitude are also extended to all staff of Fermentation Technology Laboratory especially to Mr. Rosli Aslim, Mrs. Aluyah Marzuki, Mrs. Renuga a/p Panjamurti and Mrs Latifah Husin for their help during to using instrument and glassware for my lab work study. Also to all my postgraduate friends: Miss Anisah Hasan, Miss Norrizan Abdul Wahab, Miss Noranizam Azali, Miss Julia, Miss Suhaila, Miss Azlian, Miss Madihah, Miss Nor'aini, Miss Jameah and Mr. Khaw Teik Seong of the Department of Biotechnology-UPM for their help towards the success of this project.

TABLE OF CONTENTS

Page

DEDICATION ii
ABSTRACT iii
ABSTRAK v
ACKNOWLEDGEMENTS vii
APPROVAL SHEETS viii
DECLARATION FORM x
LIST OF TABLES xiv
LIST OF FIGURES xv
LIST OF ABBREVIATIONS xvii

CHAPTER

1 **INTRODUCTION** 1

2 **LITERATURE REVIEW** 5
2.1 Water Pollution and Wastewater 5
2.1.1 Characteristic of the Wastewater 6
2.2 Treatment of Wastewater 8
2.3 Ammonium Pollution in the Wastewater 11
2.3.1 The Characteristic of Ammonium 15
2.3.2 Utilizing of Ammonium-Nitrification 16
2.3.3 Application of Ammonium in Industry 19
2.3.4 Hazardous and Toxicity of Ammonium 20
2.3.5 Method of Ammonium Removal from Wastewater 22
2.4 Zeolite 25
2.4.1 The History of Zeolite 26
2.4.2 Hydrothermal Zeolite Synthesis-Zeolite Formation 27
2.4.3 Hydrolysis 28
2.4.4 Physical Structure of Zeolite 29
2.4.5 Structural Chemical Aspects of Zeolite 31
2.4.6 Intracrystalline Diffusion 33
2.4.7 Nature of the Active Site 33
2.5 Mordenite 36
2.5.1 Properties of Mordenite 36
2.5.2 Structure of Mordenite 40
2.5.3 Hydrogen Zeolite 41
2.6 Adsorption of Adsorbates Using Zeolite 42
2.6.1 Carbon Adsorption 45
2.7 Mechanism 46
2.7.1 Adsorption 46
2.7.2 Ion-exchange 51
2.8 Kinetics of Adsorption Isotherm Parameter Estimation 54
2.8.1 Langmuir Model 55

2.8.2 Scatchard Model 57
2.9 The Advantages of Using Zeolite 58
2.9.1 Regeneration 60
2.9.2 Forward and Reverse-flow Regeneration 63
2.9.3 Other Uses of Zeolite 64

3 **GENERAL MATERIALS AND METHODS** 66
3.1 Preparation of Mordenite Particles 66
3.2 Preparation of Ammonium Stock Solution 67
3.3 Nessler Method 67
3.4 Experimental Design 68

4 **KINETICS AND MECHANISM OF AMMONIUM ADSORPTION BY MORDENITE** 69
4.1 Introduction 69
4.2 Materials and Methods 70
4.2.1 SEM 72
4.2.2 FTIR 73
4.2.3 Equilibrium removal of ammonium ion 74
4.3 Results and Discussions 75
4.3.1 Effect on Ammonium Adsorption 75
4.3.1.1 Time Course of Ammonium Adsorption .. 75
4.3.1.2 Effect of Mordenite Particle Size 77
4.3.1.3 Effect of Ammonium Concentration 78
4.3.1.4 Effect of Mordenite Concentration 80
4.3.1.5 Effect of Temperature 81
4.3.1.6 Effect of Agitation Speed 83
4.3.1.7 Effect of Initial pH 84
4.3.1.8 Application of Optimum Condition 88
4.3.2 The Ratio of Initial Ammonium/Mordenite Concentrations 88
4.3.3 Adsorption of Other Ions by Mordenite 90
4.3.4 Adsorption of Ammonium Other Adsorbent 90
4.3.5 Adsorption Kinetics 91
4.3.6 Langmuir Model 93
4.3.7 Scatchard Model 96
4.3.8 SEM 97
4.3.9 FTIR 97
4.4 Conclusion 101

5 **ADSORPTION OF AMMONIUM BY MORDENITE USING STIRRED TANK BATCH REACTOR** 103
5.1 Introduction 103
5.2 Materials and Methods 106
5.2.1 Effect of Agitation Speed 106
5.2.2 Effect of Mordenite and Ammonium Concentrations 106

5.2.3 Adsorption with Sequential Feeding..... 107
5.3 Results and Discussions..... 108
5.3.1 Effect of Agitation Speed..... 108
5.3.2 Effect of Mordenite Concentration..... 110
5.3.3 Effect of Ammonium Concentration 111
5.3.4 Final pH of Ammonium Adsorption..... 113
5.3.5 Ammonium Adsorption using Sequential Feeding Reactor..... 114
5.4 Conclusion..... 117

6 **REMOVAL OF AMMONIUM FROM SOLUTION USING PACKED-BED COLUMN**..... 118
6.1 Introduction..... 118
6.2 Materials and Methods..... 121
6.3 Results and Discussions..... 122
6.3.1 Effect of Flow Rate 122
6.3.2 Effect of Weight of Mordenite in the Column..... 125
6.3.3 Final pH of Ammonium Adsorption in the Column.. 127
6.4 Conclusion..... 129

7 **DESORPTION IN THE SHAKE FLASK AND FIXED PACKED-BED COLUMN**..... 130
7.1 Introduction..... 130
7.2 Materials and Methods..... 131
7.2.1 Shake Flask Desorption..... 131
7.2.2 Column Desorption..... 131
7.2.3 Percent Recoveries..... 132
7.3 Results and Discussions..... 132
7.4 Conclusion..... 135

8 **GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS**..... 136
8.1 General Discussions..... 136
8.2 General Conclusions..... 137
8.3 Recomendations..... 138

BIBLIOGRAPHY..... 139

APPENDIXES..... 150

VITA..... 151

LIST OF TABLES

Table		Page
1	The Characteristic of Typical Domestic Sewage at Five Countries.	6
2	Typical Removal Efficiencies of Total Nitrogen.....	11
3	Peninsular Malaysia: Rate of Change of Index of Ammoniacal Nitrogen.....	13
4	Proposed Interim National for Malaysia and DOE of Ammoniacal Nitrogen.....	14
5	Status of River Content Ammoniacal Nitrogen in Malaysia	14
6	The Other Used of Ammonium.....	20
7	Elemental Composition of Natural Mordenite.....	38
8	The Characteristic of the Mordenite.....	38
9	The Typical Characteristic of the Mordenite.....	39
10	Comparison of Ammonium Adsorption by Certain Zeolite With Other Adsorbates in Different Contactor.....	43
11	The Characteristic of Physical and Chemical Adsorption.....	50
12	Parameter of Ammonium Adsorption Using Mordenite	72
13	The Stretching Mode of Ammonium with the Location of Adsorption.....	98

LIST OF FIGURES

Figure		Page
1	Wastewater Nitrogen Cycles.....	17
2	Diagram of the "Surface" of a Zeolite Framework.....	35
3	Schematic Representation of the Mordenite Structure.....	37
4	Sheet Projection of Mordenite Showing 12- and 8- Member Rings..	37
5	The Adsorption of Ammonium on the Surface of Mordenite.....	48
6	Mechanism of Ion Exchange of Zeolite in the Solution.....	53
7	Experimental Design of Ammonium Adsorption at Different Parameter.....	68
8	Effect of Time Course of Ammonium Adsorption in Shake Flask...	76
9	Effect of Particle Size of Mordenite	76
10	Effect of Ammonium Concentration	79
11	Effect of Mordenite Concentration.....	79
12	Effect of Temperature of Solution	82
13	Effect of Agitation Speed Ranges from 50-250 rpm of Ammonium Ion Adsorption using 3 g/L Mordenite.....	82
14	Ammonium Adsorption by Mordenite at Different of Initial pH....	86
15	Final pH of Ammonium Solution When Initial pH was Fixed at 6.5..	86
16	The Ratio of Initial Ammonium /Mordenite Concentration on Ammonium Ion Uptake.....	89
17	Adsorption of Various Ions (Ammonium, Phosphorus And sulfate) by Mordenite.....	89
18	Comparison Adsorption of Ammonium ion Using Other Adsorbent.	92
19	Linear Isotherm of Langmuir Adsorption of Ammonium ion Removal by Mordenite at Different Initial Concentration.....	92

20 Non-linear Isotherm of Langmuir Adsorption of Ammonium Removal By Mordenite at Different Initial Concentrations..... 95

21 Non-linear Isotherm of Scatchard Model Adsorption Removal by Mordenite at Different Initial Concentrations..... 95

22 Typical SEM Micrographs of Natural (A) and Ammonium Exposed Mordenite (B)..... 99

23 Photoacoutic FTIR of the Natural Mordenite (Bottom line) and Ammonium Exposed Mordenite (Top line)..... 100

24 The Mechanism of Ammonium Adsorption in the Stirred Tank Batch Reactor..... 103

25 Ammonium Adsorption by Mordenite at Different Degree of Agitations using 2 L Stirred Tank Batch Reactor..... 109

26 Different Mordenite Concentrations on Ammonium Uptake in the Stirred Tank Batch Reactor..... 109

27 Graph Different Concentrations of Ammonium Ion in the 2 L Stirred Tank Batch Reactor..... 112

28 Graph Adsorption of Ammonium by Mordenite with obtained the Final pH of Solution in the Stirred Tank Batch Reactor..... 112

29 Adsorption of Ammonium using Mordenite in the Sequential Feeding Reactor..... 116

30 Graph Adsorption of Ammonium Using Mordenite in the Sequential Feeding Reactor..... 116

31 Effect of Different Flow rates of Ammonium Solution in the Down-flow Packed-bed Column on Adsorption of Ammonium by Mordenite... 124

32 Graph Different Weights and Heights of Mordenite in the Packed Bed Column..... 124

33 Final pH of Ammonium Adsorption in the Packed-Bed Column... 128

34 Desorption of Loaded Mordenite using Na^+ pH 12 in the Shake Flask Experiment..... 133

35 Graph Desorption of Loaded Mordenite in Different Weights of Mordenite using Na^+ pH 12 in the Packed-Bed Column..... 133

LIST OF ABBREVIATIONS

Ca	Calcium
C_{eq}	Adsorbate concentration at equilibrium (mg/L)
Cl	Chlorine
C_o	Initial adsorbate concentration (mg/L)
COD	Chemical oxygen demand
Cs	Cesium
DOE	Development of Environment
EC	Environmental Center
H	Hydrogen
H_3O	Hydrosonium ion
ΔH^o	Standard enthalpy
INWQS	The Interim National Water Quality Standard
K	Potassium
Mg	Magnesium
Na	Sodium
NH_3	Ammonia gas
NH_4^+	Ammonium ion
Nif	nitrogen fixation
O&G	oil and grease
OH^-	Hydroxyl ion
pH	Hydrogen potential
Q	Experimental maximum ammonium ion adsorption (mg/g)
q	Amount of adsorbate adsorbed at time t (mg/g)
q_o	Amount of adsorbate adsorbed per unit weight of adsorbent at the beginning of adsorption process (mg/g)
q_{eq}	Amount of adsorbate adsorbed per unit weight of adsorbent at equilibrium (mg/g)
Rb	Rubidium
SEM	Surface Electron Microscope
t	Time (minute)
TMA	Tetramethylammonium
TOC	Total organic carbon
TSS	Total Suspended solid
US	United State
V_o	Volume of solution in the contactor (L)
WHO	The World Health Organization
WQI	Water Quality Index
Wt	Weight
X_o	Amount or weight of adsorbent in the contactor (g)
Zeo	Zeolite

CHAPTER 1

INTRODUCTION

Nowadays our environments are exposed to polluted water such as domestic sewage, industrial and animal wastewaters. The basic component of municipal wastewater is a mixture of domestic wastewater with small amounts of industrial, agro-zoo-technical and housing wastewater (Negulescu, 1986) and its composition varies from town to town. This type of wastewater is harmful to the environment if discharged at high concentrations because it contains solids, heavy metals and other organic compounds. One of the compounds in municipal wastewater is ammonium, which is present in wastewater streams including municipal, industrial and animal wastewaters. The concentration of ammoniacal nitrogen in raw domestic wastewater ranged from 12 to 50 mg/L (Long, 1990).

Generally, un-ionized ammonium enters water system as a pollutant and may become toxic to fish if nitrification does not convert the reduced form to nitrite and ultimately to nitrate (Thurston *et al.*, 1978). High amounts of ammonia in water supply also increases the chlorine dosage required achieving free residual chlorine in disinfection. When ammonia is present in the raw water at concentration higher than 0.3 mg/L, it can cause an unpleasant taste and odor when it is allowed to degrade anaerobically during treatment (Long, 1990). For this reason, ammonia in wastewater has to be reduced to concentration lower than

0.2 mg/L before discharging to the river. The DOE Standard A show that the level of ammoniacal nitrogen in water supply and fishery uses is < 0.1 mg/L (Ministry of Agriculture, 1995). Out of 53 rivers monitored in Malaysia, as analyzed based on ammonical nitrogen index (Environmental Quality Report, 1990) (42%) was seriously polluted, 18 rivers (34%) were slightly polluted and 13 rivers (24%) were clean.

Activated carbon is known to effectively remove organic chemicals from water but ineffective for removing ammonia (Dawson *et al.*, 1976). Nitrification method, which has been used for treatment of wastewater is complicated and expensive. The usage of alum in the tap water treatment may end up as aluminium sulfate, which could endanger our health. Aluminium poisoning giving rise to tremors, loss of memory and jerking has first been reported in 1921 and there is evidence that aluminium can be a neurotoxin (Albery, 1996). Therefore, new alternative method to solve this problem of water treatment is urgently needed. There were some reports on the utilization of zeolite in wastewater treatment (Gottardi and Galli, 1985). Zeolite can be used as adsorbent to remove ammonium from solution. The first commercial application of zeolites, based on adsorption phenomenon was for the removal of ammonia from the effluent as the secondary step in the treatment of domestic wastewater (Gottardi and Galli, 1985).

Zeolites are inorganic aluminosilicate mineral containing exchangeable alkali and alkaline earth metal cations (Ca^{2+}, Na^{+}, K^{+} and Mg^{2+}), that can be found

in cavities in basaltic rocks. It is a sedimentary rock that was formed from hydrothermal alteration of volcanic rock, which is widely found in Indonesia. Having a high selectivity for ammonium, mordenite were considered to be the optimal zeolite for the removal of ammonium. It is also considered as a molecular sieve due to the pores roughly from 3-10 Å in the internal and external surface (Barrer, 1978). Zeolite is widely used in wastewater treatment because of its commercial factors such as 1) low cost, 2) good structural chemistry, 3) availability and 4) stability in a wide pH range 4-12. In 1970s, natural zeolites have became more significant to scientists who discover specifically their valuable chemical and physical properties, their large mineable deposits, and their potential application in industry and agricultural technology (Ouki *et al.*, 1994). Zeolites are used to adsorb a variety of materials such as inorganic compound, heavy metal (Pb, Ni, Zn), radioactive and others compound in the wastewater.

In this study, the effectiveness of ammonium removal by mordenite, one of the zeolite was determined. In this case, mordenite is used as the adsorbent and ammonium solution is the adsorbate. The kinetics of adsorption was studied using shake flask experiment. Experiments were undertaken to characterize the mordenite in terms of its rate of ammonium ion adsorption under various conditions. Equilibrium data from the uptake capacity of ammonium ions was analyzed using Langmuir and Scatchard adsorption isotherm model. The mechanism of NH_4^+ adsorption in the mordenite was also studied using electron microscope and FTIR technique. The adsorption of ammonium using reactor and

packed-bed column was investigated. Desorption of loaded mordenite using Na^+ pH 12 was also investigated. This parameter can be applied in wastewater treatment to remove ammonium in solution form.

The objectives of this study are:

1) To study the kinetics and mechanism of ammonium adsorption by mordenite using shake flask experiment.
2) To study the effect of different adsorption conditions especially particle size of mordenite, ammonium concentration, mordenite concentration, pH, temperature and agitation speed on the efficiency of ammonium adsorption by mordenite.
3) To compare the performance of ammonium adsorption by mordenite in different contactors (shake flask, batch stirred tank reactor, sequential feeding reactor and fixed packed-bed column).

CHAPTER 2

LITERATURE REVIEW

2.1 Water Pollution and Wastewater

A supply of clean water is an essential requirement for the establishment and maintenance of a healthy community. Its acts not only as a source of potable water, but also provides valuable food supplements through supporting the growth of aquatic life, and also by its usage for irrigation in agriculture. Water, which has been utilized and discharged from domestic dwellings, institutions and commercial establishments, leachates from solid waste disposal sites, together with water discharged from manufacturing industries, contains a large number of potentially harmful compounds. Consequently, if it is discharged directly into a watercourse, serious damage might result to the many forms of life which inhabit this water. To ensure that such problems are avoided or minimized, attention should be paid to the management of our aquatic resources and also of the pollutants which enter them (Horan, 1990).

The organic and inorganic components of wastewater are present in both soluble and insoluble form. Watercourses receive pollution from many different sources, which vary both in strength and volume. Identification of the major sources of these pollutants is important, as they can be controlled most easily at the source (Long, 1990). The main source of both chemical and biological

pollution in domestic sewage resulted from human excreta with a smaller contribution from wastewater resulting from laundry, food preparation and bath (Horan, 1990). The characteristic of typical domestic sewage at five countries is illustrated in Table 1 below:

Table 1: The Characteristic of Typical Domestic Sewage at Five Countries (Horan, 1990).

Determinant	Manchester (UK)	Mafraq (Abu Dhabi town)	Campina Grande (NE Brazil)	Amman (Jordan)	Nairobi (Kenya)
BOD (mg O_2/L)	240	228	240	770	520
COD (mgO_2/L)	520	600	570	1830	520
PV (mgO_2/L)	-	75	-	-	-
Suspended solids (mg/L)	210	198	392	900	520
Ammonia (as N (mg/L)	**22**	**35.2**	**38**	**100**	**33**
PH	7.4	7.6	7.8	-	7.0
Temperature (°C)	14	-	2.6	22	24

2.1.1 Characteristics of the Wastewater

In general, wastewater can be characterized based on its bulk organic parameters, physical characteristics and specific contaminants. The bulk organic wastewater quality parameters measure the amount of organic matter present in a waste stream (Belhateche, 1995). Typical parameters are total organic carbon (TOC), chemical oxygen demand (COD) and oil and grease (O&G). All these parameters measurements indicate the amount of organic matter present in a

waste stream that require stabilization or oxidation stream (Belhateche, 1995). These parameters are useful for measuring the organic quality of wastewater only when such compounds are expected to be present in large qualities, such as in refinery wastewater as shown below:

1) Physical characteristics - The physical characteristics of wastewater include total suspended solids (TSS), temperature, pH, color, odour, turbidity, flow variability, conductivity, settleability and sometimes oxidation/reduction (redox) potential (Long, 1990).

2) Biological characteristics - Bacteriological testing determines the presence of pathogenic (disease causing) organisms or indicator bacteria for such organisms in the raw wastewater, processed streams, and treated effluent (Long, 1990).

3) Chemical composition - chemical testing provides information on the concentrations of the specific substances for which the tests are designed. The determination composition of wastewater include pH, alkalinity, solids, BOD (Biological oxygen demand), COD (Chemical Oxygen Demand), Nitrogen-organic nitrogen, ammonia, nitrite and nitrate, phosphorus, chlorine, sulfide, fat-oils-greases and priority pollutants (Long, 1990).