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Title PROPERTIES AND BIODEGRADABILITY OF WASTE PAPER
FILLED POLYURETHANE FOAMS COMPOSITES.
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TABLE OF CONTENTS

	Pages
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS	v
LIST OF FIGURES	x
LIST OF TABLES	xvi
LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURES	xviii
ABSTRAK	xxi
ABSTRACT	xxii

CHAPTER 1. INTRODUCTION

1.1	Research Background	1
	1.1.1 The Necessity for Biodegradable Plastic	1
	1.1.2 Reuse Waste Materials	4
1.2	Research Objective	5

CHAPTER 2. LITERATURE REVIEW

2.1	Introduction to Polyurethane	7
	2.1.1 Basic Polyurethane Chemistry	8
2.2	Polymeric Foams	10
	2.2.1 Flexible Polyurethane Foam Chemistry	10
	2.2.2 General Chemical Reactions	10
	2.2.3 Blow Reaction	11
	2.2.4 Gelation Reaction	12

2.2.5	Basic Foam Components	16
2.2.6	Isocyanates	17
2.2.7	Diphenyl methane 4,4-diisocyanate (MDI)	20
2.2.8	Polyols	22
2.2.9	Water	27
2.3	Foam Fundamentals	28
2.3.1	Foam Structure	29
2.3.1.1	Compression Properties	32
2.3.2	The Foaming Process	34
2.3.3	Raw Material Conditioning	34
2.3.4	Mixing	35
2.4	Cell Growth	37
2.4.1	Cell Opening	39
2.4.2	Cure	40
2.5	Surfactant	42
2.6	Catalysts	43
2.6.1	Tertiary Amine Catalysts	45
2.6.2	Organometallic Catalysts	47
2.6.3	Triethylene diamine (TEDA)	48
2.6.4	Methylene chloride (MC)	49
2.7	Fillers or Extenders	50
2.7.1	Waste paper	51
2.7.2	Polyurethane foam extended with biomass materials	53
2.8	Biodegradable of Foam	58
2.9	Thermal Analysis	59

CHAPTER 3. RESEARCH METHODOLOGY

3.1	Materials	61
3.1.1	Raw Materials	61

3.1.2 Filler	61
3.1.2.1 Paper Sludge	62
3.1.2.2 Office White Paper/Old Newspaper	62
3.1.3 Catalysts	64
3.2 Preparation of Waste Paper Foam Composites	64
3.2.1 Preparation of Waste Paper Foam with Different Filler Loading	64
3.2.1.1 Preparation of waste paper foam with different catalyst	65
3.2.1.2 Preparation of Partial Replacement TDI in MDI Old Newspaper Foam Composites	66
3.3 Physical and Mechanical Properties Measurements	67
3.3.1 Density Test	67
3.3.2 Compression Test	68
3.3.3 Hardness Test	69
3.3.4 Morphology Study	69
3.3.5 Biodegradable Test	70
3.3.6 Thermogravimetry Analysis (TGA)	71

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Effect of Different Types and Loading of Waste Paper Filled Polyurethane Foam Composites	72
4.1.1 Compressive Strength	72
4.1.2 Compressive Modulus	73
4.1.3 Density Properties	75
4.1.4 Hardness	76
4.1.5 Morphology Study	77
4.1.6 Thermogravimetric analysis (TGA)	82
4.1.7 Biodegradable Properties	87
4.2 Effect of Triethylene Diamine (TEDA) on Properties of Waste Paper Filled Polyurethane Foam Composites.	94
4.2.1 Compressive Strength	94

4.2.2	Compressive Modulus	97
4.2.3	Density Properties	100
4.2.4	Hardness	102
4.2.5	Morphology Study	105
4.2.6	Thermogravimetric analysis (TGA)	109
4.3	Effect of Methylene Chloride (MC) on Properties of Waste Paper Filled Polyurethane Foam Composites.	115
4.3.1	Compressive Strength	115
4.3.2	Compressive Modulus	117
4.3.3	Density Properties	118
4.3.4	Hardness	120
4.3.5	Morphology Study	122
4.3.6	Thermogravimetric analysis (TGA)	126
4.4	Effect of Different Types and Loading of Old Newspaper on Partial Replacement of TDI in MDI Foam Composites.	132
4.4.1	Compressive Strength	132
4.4.2	Compressive Modulus	133
4.4.3	Density Properties	133
4.4.4	Hardness	134
4.4.5	Morphology Study	135
4.4.6	Thermogravimetric analysis (TGA)	137

CHAPTER 5. CONCLUSIONS AND SUGGESTION FOR FURTHER WORK

5.1	Conclusions	140
5.2	Suggestion for Further Work	142

REFERENCES	143
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APPENDIX A	154
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APPENDIX B	155
APPENDIX C	156
APPENDIX D	157
APPENDIX E	158
APPENDIX F	159
APPENDIX G	160
APPENDIX H	161

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LIST OF FIGURES

		Pages
Figure 2.1	Reaction between a polyisocyanate and polyol to form urethane.	8
Figure 2.2	Formation of urethane network.	9
Figure 2.3	First step of the blow reaction.	11
Figure 2.4	Second step of the blow reaction.	12
Figure 2.5	Formation of a biuret linkage.	12
Figure 2.6	The gelation or cross-linking reaction.	13
Figure 2.7	Formation of an allophanate linkage.	13
Figure 2.8	Schematic representation of the phase separation behavior in Polyurethane foams (Herrington & Hock, 1998).	15
Figure 2.9	Isomers of Toluene Diisocyanate.	18
Figure 2.10	Routes for the production of commercial TDI blends (Herrington & Hock, 1998).	19
Figure 2.11	Diphenyl methane 4,4-diisocyanate.	21
Figure 2.12	Repeat units of the common polyether polyols used in flexible foam production (Herrington & Hock, 1998).	23
Figure 2.13	Base catalyzed production of poly(propylene oxide) (Herrington & Hock, 1998).	24
Figure 2.14	Mechanism of base catalyzed ring-opening polymerization (Woods, 1982).	25
Figure 2.15	Side reaction resulting in a monofunctional chain (monol) (Woods, 1982).	26
Figure 2.16	Schematic compression stress-strain curve for a foam.	33

Figure 2.17	N,N-Dimethylcyclohexylamine.	45
Figure 2.18	Triethylenediamine.	46
Figure 2.19	Dichloromethane.	50
Figure 2.20	Molecule structure of cellulose.	53
Figure 3.1	Compression testing.	68
Figure 3.2	Scanning electron microscope machine model JSM-6-160LA.	70
Figure 4.1	The effect of different waste paper loading on compressive strength of polyurethane foam composites.	73
Figure 4.2	The effect of different waste paper loading on compressive modulus of polyurethane foam composites.	74
Figure 4.3	Effect of different waste paper loading on density of polyurethane foam composites.	76
Figure 4.4	The effect of different waste paper loading on hardness of polyurethane foam composites.	77
Figure 4.5	Scanning electron micrograph of polyurethane foam at magnification 50X.	79
Figure 4.6	Scanning electron micrograph of paper sludge foam composites (20 php PS) at magnification 50X.	79
Figure 4.7	Scanning electron micrograph of paper sludge foam composites (40 php PS) at magnification 50X.	80
Figure 4.8	Scanning electron micrograph of office white paper foam composites (20 php OWP) at magnification 50X.	80
Figure 4.9	Scanning electron micrograph of office white paper foam composites (40 php OWP) at magnification 50X.	81
Figure 4.10	Scanning electron micrograph of old newspaper foam composites (20 php ONP) at magnification 50X.	81
Figure 4.11	Scanning electron micrograph of old newspaper foam (40 php ONP) at magnification 50X.	82
Figure 4.12	Thermogravimetric analysis (TGA) curves of paper sludge foam composites at different filler loading.	84

Figure 4.13	Thermogravimetric analysis (TGA) curves of OWP foam composites at different filler loading.	84
Figure 4.14	Thermogravimetric analysis (TGA) curves of ONP foam composites at different filler loading.	85
Figure 4.15	Effect of biodegradation on the weight loss of PS foam composites.	88
Figure 4.16	Effect of biodegradation on the weight loss of OWP foam composites.	88
Figure 4.17	Effect of biodegradation on the weight loss of ONP foam composites.	89
Figure 4.18	Scanning electron micrograph of PU foam after 6 months buried in soil.	90
Figure 4.19	The scanning electron microscope of PS foam composites (20 php PS) after 6 months buried in soil at magnification 50X.	91
Figure 4.20	The scanning electron microscope of PS foam composites (40 php PS) after 6 months buried in soil at magnification 50X.	91
Figure 4.21	The scanning electron microscope of OWP foam composites (20 php OWP) after 6 months buried in soil at magnification 50X.	92
Figure 4.22	The scanning electron microscope of OWP foam composites (40 php OWP) after 6 months in soil at magnification 50X.	92
Figure 4.23	The scanning electron microscope of ONP foam composites (20 php ONP) after 6 months in soil at magnification 50X.	93
Figure 4.24	The scanning electron microscope of ONP foam composites (40 php ONP) after 6 months in soil at magnification 50X.	93
Figure 4.25	The effect of PS loading on compressive strength of PS foam composites with and without TEDA catalyst.	95
Figure 4.26	The effect of OWP loading on compressive strength of OWP foam composites with and without TEDA catalyst.	95
Figure 4.27	The effect of ONP loading on compressive strength of ONP foam composites with and without TEDA catalyst.	96
Figure 4.28	The effect of different waste paper loading on compressive strength of waste paper foam composites with TEDA catalyst.	96
Figure 4.29	The effect of PS loading on compressive modulus of PS foam composites with and without TEDA catalyst.	98

Figure 4.30	The effect of OWP loading on compressive modulus of OWP foam composites with and without TEDA catalyst.	98
Figure 4.31	The effect of ONP loading on compressive modulus of ONP foam composites with and without TEDA catalyst.	99
Figure 4.32	The effect of different waste paper loading on compressive modulus of waste paper foam composites with TEDA catalyst.	99
Figure 4.33	The effect of different waste paper loading on the density of waste paper foam composites with TEDA catalyst.	101
Figure 4.34	The effect of PS loading on density of PS foam composites with and without TEDA.	101
Figure 4.35	The effect of PS loading on hardness of PS foam composites with and without TEDA catalyst.	103
Figure 4.36	The effect of OWP loading on hardness of OWP foam composites with and without TEDA catalyst.	103
Figure 4.37	The effect of ONP loading on hardness of ONP foam composites with and without TEDA catalyst.	104
Figure 4.38	The effect of waste paper loading on the hardness of waste paper foam with TEDA catalyst.	104
Figure 4.39	Scanning electron micrograph of polyurethane foam with TEDA catalyst at magnification 50X.	106
Figure 4.40	Scanning electron micrograph of PS foam composite (20 php PS) with TEDA catalyst at magnification 50X.	106
Figure 4.41	Scanning electron micrograph of PS foam composite (40 php PS) with TEDA catalyst at magnification 50X.	107
Figure 4.42	Scanning electron micrograph of OWP foam composite (20 php OWP) with TEDA catalyst at magnification 50X.	107
Figure 4.43	Scanning electron micrograph of OWP foam composite (40 php OWP) with TEDA catalyst at magnification 50X.	108
Figure 4.44	Scanning electron micrograph of ONP foam composite (20 php ONP) with TEDA catalyst at magnification 50X.	108
Figure 4.45	Scanning electron micrograph of ONP foam composite (40 php ONP) with TEDA catalyst at magnification 50X.	109
Figure 4.46	Thermogravimetric analysis (TGA) curves of old newspaper composites foam with TEDA at 0, 20, 40 php ONP.	111

Figure 4.47	Thermogravimetric analysis (TGA) curves of old newspaper foam composites (40 php ONP) with and without TEDA.	111
Figure 4.48	The effect of ONP loading on the compressive strength of ONP foam composites with and without MC catalyst.	116
Figure 4.49	The effect of filler loading on the compressive strength of waste paper foam composites with methylene chloride (MC).	116
Figure 4.50	The effect of ONP loading on the elastic modulus of ONP foams composites with and without MC catalyst.	117
Figure 4.51	The effect of filler loading on the compressive modulus of waste paper foams composites with MC catalyst.	118
Figure 4.52	The effect of different waste paper loading on density of waste paper foam composites with MC catalyst.	119
Figure 4.53	The effect of PS loading on density of PS foam composites with and without MC catalyst.	119
Figure 4.54	The effect of PS loading on hardness of PS foam composites with and without MC catalyst.	120
Figure 4.55	The effect of OWP loading on hardness of OWP foam composites with and without MC catalyst.	121
Figure 4.56	The effect of ONP loading on hardness of ONP foam composites with and without MC catalyst.	121
Figure 4.57	The effect of waste paper loading on the hardness of waste paper foam with MC catalyst.	122
Figure 4.58	Scanning electron micrograph of polyurethane foam composites with MC catalyst at magnification 50X.	123
Figure 4.59	Scanning electron micrograph of PS foam composites (20 php PS) with MC catalyst at magnification 50X.	123
Figure 4.60	Scanning electron micrograph of PS foam composites (40 php) with MC catalyst at magnification 50X.	124
Figure 4.61	Scanning electron micrograph of OWP foam composites (20 php OWP) with MC catalyst at magnification 50X.	124
Figure 4.62	Scanning electron micrograph of OWP foam composites (40 php OWP) with MC catalyst at magnification 50X.	125
Figure 4.63	Scanning electron micrograph of ONP foam composites (20 php ONP) with MC catalyst at magnification 50X.	125

Figure 4.64	Scanning electron micrograph of ONP foam composites (40 php ONP) with MC at magnification 50X.	126
Figure 4.65	Thermogravimetric analysis (TGA) curves of old newspaper foam composites with MC catalyst at different loading.	127
Figure 4.66	Thermogravimetric analysis (TGA) curves of old newspaper foam composites (40 php ONP) with and without MC catalyst.	128
Figure 4.67	Compressive strength of MDI/ONP and TDI/MDI/ONP foam composites with different filler loading.	132
Figure 4.68	Compressive modulus of MDI/ONP foam and MDI/TDI/ONP foam composites with different filler loading.	133
Figure 4.69	Density of MDI/ONP foam and MDI/TDI/ONP foam composites with different filler loading.	134
Figure 4.70	Hardness of MDI/ONP and MDI/TDI/ONP foam composites with different filler loading.	135
Figure 4.71	Scanning electron micrograph of TDI/MDI/ONP foam composites at magnification 50X.	136
Figure 4.72	Scanning electron micrograph of TDI/MDI/ONP foam composites (20 php ONP) at magnification 50X.	136
Figure 4.73	Scanning electron micrograph of TDI/MDI/ONP foam composites (40 php ONP) at magnification 50X.	137
Figure 4.74	Thermogravimetric analysis (TGA) curves of TDI/MDI/ONP composites foam with different filler loading.	138
Figure 4.75	Comparison thermogravimetric analysis (TGA) curves of MDI/ONP and TDI/MDI/ONP foam composites.	138

LIST OF TABLES

		Pages
Table 2.1	Reactivity of Isocyanates with Active Hydrogen Compounds (Herrington & Hock, 1998).	14
Table 2.2	Formulation Basics for Flexible Polyurethane Foams (Herrington & Hock, 1998).	17
Table 2.3	Diphenyl methane 4,4-diisocyanate (MDI) physical properties (Ulrich, 1996).	21
Table 3.1	Semi quantitative analysis of wastw paper using an X-Ray Fluorescences Spectrometer Rigaku RIX 3000.	63
Table 3.2	Formulation of waste paper foam composites.	65
Table 3.3	Formulation of waste paper foam composites with triethylene diamine TEDA and methylene chloride (MC).	66
Table 3.4	Formulation of MDI/TDI/PEG with old newspaper foam composites.	67
Table 4.1	Percentage weight loss of paper sludge (PS) foam composites at different temperature and loading.	85
Table 4.2	Percentage weight loss of office white paper (OWP) foam composites at different temperature and loading.	86
Table 4.3	Percentage weight loss of old newspaper (ONP) foam composites at different temperature and loading.	86
Table 4.4	Weight loss of waste paper foam composites after biodegradable in soil for 6 months.	89
Table 4.5	Percentage weight loss of paper sludge (PS) foam composites produced with and without TEDA at different temperature.	112
Table 4.6	Percentage weight loss of office white paper (OWP) foam composites with and without TEDA at different temperature.	113

Table 4.7	Percentage weight loss of old newspaper (ONP) foam composites with and without TEDA at different temperature.	114
Table 4.8	Percentage weight loss of paper sludge (PS) foam composites with and without MC catalyst at different temperature.	129
Table 4.9	Percentage weight loss of office white paper (OWP) foam composites with and without MC catalyst at different temperature.	130
Table 4.10	Percentage weight loss of old newspaper (ONP) foam composites with and without MC catalyst at different temperature.	131
Table 4.11	Percentage weight loss of MDI/ONP and TDI/MDI/ONP foam at different temperature.	139

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURES

μ	Micron
μm	Micro meter
ABA	Alternative blowing agents
ASTM	American Society for Testing and Materials
CFC	Chlorofluorohydrocarbons
CO_2	Carbon dioxide
DBTL	dibutyl tin dilaurate
DCM	Dichloromethane
DSC	Differential Scanning Calorimetry
EO	Ethylene oxide
FPF	Flexible polyurethane foam
FTIR	Fourier transform infrared spectroscopy
HDI	Hexamethylene diisocyanate
HFC	Hydrofluorocarbons
HR	High resiliency
IPDI	Isophorone diisocyanate
kg	Kilogram
LOI	Loss on ignition
<i>m</i>	mass
MC	Methylene Chloride

Md	Mass after hydrolysis
MDI	Diphenyl methane 4,4'-diisocyanate
MEKO	Methyl ethyl ketoxime
min	minute
mm	milimeter
Mo	Mass before hydrolysis
MPW	Mixed-paper waste
OWP	Office White Paper
ONP	Old Newspaper
Pd	Palladium
PEG	Polyethylene glycol
PMDI	Polymeric diphenyl methane 4,4'-diisocyanate
pphp	Parts per hundred polyol
PS	Paper Sludge
PU	Polyurethane
SEM	Scanning electron microscope
RNHCOOH	Carbamic acid
T	Temperature
T _c	Crystallization temperature
T _g	Glass transition temperature
T _m	Melting temperature
TDI	Toluylene 2,4-diisocyanate
TEDA	Triethylene diamine

TGA	Thermogravimetry Analysis
UV	Ultraviolet
v	volume
VPF	Variable pressure foaming
Wt	Weight
$\Delta H_{f(\text{com})}^{\circ}$	Heat of fusion of composites
γ	Interfacial surface tension
Φ	Relative density
P_f	Density of foam

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SIFAT-SIFAT DAN KEBOLEHBIOROSOTAN SISA KERTAS TERISI KOMPOSIT BUSA POLIURETANA

ABSTRAK

Penyelidikan difokuskan pada kajian sifat-sifat busa poliuretana diperkuat dengan sisa kertas yang berbeza jenis dan kandungan. Perbandingan ke atas kesan tiga jenis sisa kertas seperti lumpur kertas (PS), kertas putih pejabat (OWP) dan surat khabar lama (ONP) ke atas sifat-sifat fizikal, mekanikal, terma, biorosotan dan morfologi busa poliuretana telah dikaji. Hasilnya menunjukkan busa ONP nyata mempunyai nilai kekuatan mampat, modulus mampat dan kekerasan paling tinggi berbanding komposit busa PS dan OWP. Semakin meningkatnya pembebanan pengisi telah meningkatkan sifat-sifat mekanikal tetapi mengurangkan ketumpatan busa. Kajian mikroskop elektron imbasan (SEM) menunjukkan bahawa penambahan sisa kertas di dalam poliuretana mengurangkan struktur terbuka sel busa. Kajian biorosotan komposit busa sisa kertas meningkat dengan semakin meningkatnya pembebanan pengisi sisa kertas. Bagaimanapun komposit busa ONP menunjukkan perosotan yang lebih tinggi di dalam tanah berbanding busa OWP dan diikuti komposit busa PS. Keputusan analisis terma-gravimetri (TGA) menunjukkan komposit busa PS mempunyai kestabilan haba yang paling tinggi berbanding komposit busa OWP dan ONP. Kalorimetri imbasan perbezaan (DSC) menunjukkan dengan semakin meningkatnya pembebanan pengisi telah mengurangkan nilai pelakuran haba komposit dan kehabluran komposit. Komposit busa PS menunjukkan penghabluran yang paling tinggi. Kehadiran trietilena diamina (TEDA) sebagai pemangkin telah meningkatkan kekuatan mampat, modulus mampat, kekerasan, ketumpatan dan kehabluran komposit busa sisa kertas. Ketahanan terhadap terma komposit busa sisa kertas dengan TEDA adalah paling tinggi daripada komposit busa sisa kertas tanpa pemangkin. Mikrograf komposit busa sisa kertas dengan TEDA menunjukkan penambahan pengisi dan pemangkin boleh memberi kesan kepada sambung silang komposit busa untuk menghasilkan struktur sel yang kecil. Komposit busa sisa kertas dengan metilena klorida (MC) mempunyai kekuatan mampat, modulus mampat, kekerasan dan penghabluran yang lebih tinggi tetapi ketumpatan dan kestabilan haba yang rendah berbanding komposit busa sisa kertas tanpa pemangkin. Gantian separa toluena di-isocianat (TDI) di dalam difenil metana 4,4'-di-isocianat (MDI) untuk busa ONP menunjukkan kekuatan mampat, modulus mampat, kekerasan dan ketumpatan yang lebih tinggi berbanding dengan komposit busa MDI/ONP. Mikrograf komposit busa TDI/MDI/ONP menunjukkan bahawa struktur sel busa yang lebih rapat. Komposit busa TDI/MDI/ONP mempunyai kestabilan haba yang baik daripada komposit busa MDI/ONP.

PROPERTIES AND BIODEGRADABILITY OF WASTE PAPER FILLED POLYURETHANE FOAMS COMPOSITES

ABSTRACT

The research is focused to study the properties of polyurethane foam reinforced with different types and content of waste paper. The comparison of the effects of three types of waste paper, such as paper sludge (PS), old newspaper (ONP) and office white paper (OWP) on physical, mechanical, thermal, biodegradable properties and morphology of PU foam was studied. The result show ONP foam significantly highest value of compressive strength, compressive modulus and hardness compared than PS and OWP foam composites. The increasing filler loading improved the mechanical properties but reduced the density of foam. Scanning electron microscopy (SEM) study indicated that the addition of waste paper in polyurethane foam reduced the open cell structure of foam. The biodegradation study of waste paper foam composites increased with increasing of waste paper loading. However, the ONP foam composites showed higher degradation in soil compared to the OWP foam and followed by PS foam composites. The results of thermogravimetric analysis (TGA) showed PS foam composites has highest thermal stability compared with OWP and ONP foam composites. The PS foam composites exhibit the highest of crystallization. The presence of the triethylene diamine (TEDA) as catalyst has improved the compressive strength, compressive modulus, hardness and density of waste paper foam composites. The thermal stability of waste paper foam composites with TEDA is higher than waste paper foam composites without TEDA. The micrographs of waste paper foam composites with TEDA show the addition of filler and catalyst can affect the crosslinking of the foam composites to produce the smaller cell structure. The waste paper foam composites with methylene chloride (MC) have higher of compressive strength, compressive modulus and hardness but lower the density and thermal stability compare to waste paper foam composites without MC. The morphology of waste paper foam composites with different filler loading with MC show smaller open cell compared to without catalyst. Partial replacement of toluene diisocyanate (TDI) in diphenyl methane 4,4'-diisocyanate (MDI) of ONP foam indicates higher compressive strength, compressive modulus, hardness and density compared to MDI/ONP foam composites. The micrograph of TDI/MDI/ONP foam composites show that the foam close cell structure compared to MDI/ONP foam composites. The TDI/MDI/ONP foam composites have better thermal stability than MDI/ONP foam composites.

CHAPTER 1

INTRODUCTION

1.1 Research Background

1.1.1 The Necessity for Biodegradable Plastic

Disposal of plastic waste into landfills has become increasingly prohibitive due to high costs and legislative pressure. Growing environmental awareness and reductions in available landfill capacity have prompted plastics recycling programs in most developed countries (Joseph, 1995). In the past, plastic polymeric materials have been designed to degradation. However, with mounting environmental and legislative pressure to reduce plastic and packaging wastes, there has been an increased demand for biodegradable polymers that are compatible with the environment (Mohee et al., 2007). Plastic foams are synthetic polymers that are used widely throughout the world for various applications. Synthetic polymeric foams have pervaded every aspect of modern life. Although foams provide numerous benefits, they also cause a significant environmental problem because of their recalcitrant and xenobiotic nature. Biodegradation may provide solution to the problem, but not enough is known about the biodegradation process of synthetic plastic and plastic based foams (Gautam et al., 2007). Petroleum based foams

are, like most of the plastics and resins from which they are issued, non-biodegradable, even over several decades time (Perkowitz, 2000).

An obvious benefit of recycling and use of biodegradable plastic is that both reduce the requirement for landfill or incineration of waste materials. Biodegradable plastics can be managed by composting, generally perceived as more environmentally beneficial than landfill or incineration. In fact, advocates of composting often refer to it as natural or biological recycling (Fenton, 1992). Composting, in contrast, is designed to accelerate biodegradation and serve as an alternative to landfilling. Use of biodegradable plastics permits disposal through composting and therefore can reduce the burden on landfill if system to direct the product or package to composting are in place and utilized. In addition, for products that pose a litter problem, the use of biodegradable plastics can greatly reduce their prevalence and longevity in the environment (Freedonia, 2004).

The ASTM standard D5988-03, biodegradability of plastic materials has been defined as the capability of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds or biomass predominantly by the enzymatic action of microorganisms. The standard requires 60–90% decomposition of the plastic within 60–180 days in a composting environment (Mohee et al., 2007).

The increasing research interest in biodegradable polymers over the past two decades has led to the availability of a large variety of novel polymers with claims of biodegradability. Among these polymers, polyurethanes (PUs) are an interesting family of materials. The PUs are segmented multiphase elastomers. They are a unique class of polymers because a large variety of PUs with widely varying physical and chemical properties can be synthesized. Recently, biodegradable materials have gained importance