Chapter VI SUMMARY AND CONCLUSIONS

6.1. INTRODUCTION:

Synthetic polymers were originally developed for their durability and resistance to all forms of degradation, including biodegradation. These virtues of polymer have now become a greatest problem. It would be highly beneficial from the environmental stand point, if these films were biodegradable, decomposing almost completely under the attack of microorganism over a period of say few months or even they can break into fragments so that they do not become harmful to the environment. (Abraham J. Domb, et al.,G.F. Moore,et al.)

At the time of invention of polymeric material the primary concerns were about preventing or retarding the attack of bacteria, fungi, rodents, insects, and other animals on polymer. Hence various factors affecting the degradability of polymer were identified and remedial measures to overcome those factors were implemented.

Today the same factors affecting the degradability are studied to measure the extent of degradability, the duration of degradability and their effect on the properties of polymers is studied. (Leonard I. Nass, vol. I 1976).

6.2. OBJECTIVES:

◊To identify the most economical mechanism of degradation.

◊To identify the most prominent factor affecting the degradation.

◊To develop the polymer showing shortest duration of degradation.

◊To develop the polymer showing highest extent of degradation.

◊To develop the polymer showing lowest reduction in property.

◊To identify the specie of microorganism that is most susceptible to biodegradation.

◊To assess the plant toxicity of the biodegradable polymer developed.

◊To assess the fertility of the soil after land fill.

◊To carry out cost analysis of the biodegradable polymer developed.

◊Assess the commercial viability of the biodegradable polymer developed.

6.3. PLANNING OF EXPERIMENTS:

To achieve above objectives:

◊Various modes of polymer degradation were studied and the most suitable method of addition of plasticizer was selected.

◊Various plasticizers like groundnut oil and soy bean oil were selected with respect to availability, ease of processing and cost. Their effects on degradability were studied.

◊Most conventional polymers used for the manufacture of carry bags like LDPE, HDPE, PS and PP were selected.

◊Microorganisms exhibiting the highest susceptibility towards the biodegradation like Pseudomonas (Bacteria), Staphylococcus (Bacteria), E- Coli (Bacteria), Aspergillus Niger (Fungi), Rhizopus (Fungi) and Consortium - Mixed Culture of above microorganisms were selected.

◊The films from the selected polymers were manufactured by the conventional extrusion process. One specimen without plasticizer, 5 specimens with varying amount of groundnut oil and 5 specimens with varying amount of soybean oil with LDPE, HDPE, PS and PP as base polymer were prepared. 44 different specimens were manufactured by this process.

◊The specimens were tested for; Tensile impact strength, Tensile strength, Tensile elongation and Viscosity. The mechanical strength was compared with those of conventional materials.

◊The films manufactured were subjected to the microorganisms exhibiting the highest susceptibility towards the biodegradation.

◊Various standard test methods for the assessment of biodegradation viz. Screening of biodegradation of specimen in open air to assess the property loss, Screening of biodegradation of specimen in open air, Growth ratings ASTM G-21 and Plant toxicity test were applied.

◊The loss in Weight, Tensile strength, Percent elongation and Viscosity was measured to assess the biodegradability.

◊The microorganisms were isolated and the grown separately to study the structure of the microorganism.

◊The comparison of the structure of microorganism grown due to the biodegradable polymer with that of the original microorganism was carried out.

◊ The polymer exhibiting good degradability and ease of processing was identified.

◊Film from LDPE was manufactured on large scale on a conventional screw extruder to assess the ease of processing.

◊The effects of plasticizers on the processing parameters were recorded and the cost analysis of the film is carried out.

◊The film was subjected to the plant toxicity test to assess the effect of biodegradable polymer on the production of crops.

◊The soil analysis was also carried out to assess the fertility of the soil after land fill.

6.4. RESULTS:

Results from various test methods carried out were recorded as follows:

6.4.1 RESULTS FROM PROPERTY COMPARISON OF POLYMER FILMS:

Sr.No.	Specimen	Tensile Impact Kj/cm	Tensile Strength Kgf/cm^2 50mm/min	Percent Elongation	Specific Reduced Viscosity
1.	LD00	4.65	56.131	100	584.000
2.	LDG25	4.17	69.229	210	113.000

3.	LDS25	5.2	71.119	722	138.000
4.	HD00	3.65	142.710	407	1215.333
5.	HDG25	5.51	153.830	630	733.333
6.	HDS25	10.26	118.760	168	1399.000
7.	PS00	3.18	105.530	1.007	419.667
8.	PSG25	3.06	114.520	2.284	53.333
9.	PSS25	3.5	76.963	1.142	47.333
10.	PP00	4.97	121.780	226.786	511.333
11.	PPG25	4.75	97.430	1075	320.833
12.	PPS25	3.65	131.400	1285.4	455.000

6.4.2 RESULTS FROM SCREENING OF BIODEGRADATION OF SPECIMEN TO ASSESS THE PROPERTY LOSS:

6.4.2.a. PERCENT WEIGHT LOSS:

Sr.no.	Specimen	6week	8week	10week	12week
1.	LD00	15	2	2.4	6.943
2.	LDG25	10.000	1.867	8.571	1.600
3.	LDS25	17.225	22.100	16.800	11.767
4.	HD00	4.543	8.043	2.075	4.675
5.	HDG25	3.567	1.925	11.650	5.067
6.	HDS25	10.000	19.533	14.700	4.867
7.	PS00	3.743	2.150	4.940	0.200
8.	PSG25	2.050	8.940	55.260	6.127
9.	PSS25	20.000	3.640	19.800	11.600
10.	PP00	6.500	2.100	7.433	0.650
11.	PPG25	4.600	22.800	8.480	2.750
12.	PPS25	4.025	18.867	3.100	7.200

6.4.2.b. PERCENT LOSS IN TENSILE STRENGTH:

Sr. no.	Specimen	6 weeks	8 weeks	10 weeks	12 weeks
1.	LD00	30.718	59.173	59.602	65.619
2.	LDG25	60.258	66.616	68.278	68.541
3.	LDS25	48.173	48.271	50.663	69.493
4.	HD00	51.367	51.802	58.076	69.021
5.	HDG25	58.368	62.720	76.525	76.783
6.	HDS25	13.638	92.382	92.912	92.968
7.	PS00	3.134	7.098	94.691	99.483
8.	PSG25	47.885	51.910	98.298	98.441
9.	PSS25	0.052	0.052	81.802	82.938
10.	PP00	28.466	29.816	66.286	86.909
11.	PPG25	25.723	34.833	57.600	61.492
12.	PPS25	55.447	56.262	72.083	72.591

6.4.2.c. PERCENT ELONGATION LOSS:

Sr.no.	Specimen	6 week	8 week	10 week	12 week
1.	LD00	42	42	91.429	95.833
2.	LDG25	70	122.500	128.75	137.5
3.	LDS25	212	568.875	573.429	577
4.	HD00	277	374.742	377.000	379.222
5.	HDG25	546	546.667	552.581	555
6.	HDS25	46	50.000	108	78.256
7.	PS00	-38.993	-22.993	-8.368	-13.278
8.	PSG25	-3.716	-0.657	-1.883	-3.839
9.	PSS25	-0.858	-9.573	-4.41386	-1.715
10.	PP00	146.786	93.452	126.786	129.488
11.	PPG25	155	157.000	161.3636	246.429
12.	PPS25	505.4	515.400	537.5739	543.092

6.4.2.d. SPECIFIC VISCOSITY:

Sr. no.	Specimen	Initial	6 week	8 week	10 week	12 week
1.	LD00	584.000	372.614	496.065	482.165	125.627
2.	LDG25	113.000	18.905	75.977	63.177	50.192
3.	LDS25	138.000	119.629	91.854	93.979	59.249
4.	HD00	1215.333	1161.230	447.956	759.127	660.897
5.	HDG25	733.333	544.749	125.070	304.612	280.899
6.	HDS25	1399.000	838.664	357.576	1342.321	791.521
7.	PS00	419.667	50.294	79.434	15.815	122.457
8.	PSG25	53.333	43.551	33.191	53.047	24.953
9.	PSS25	47.333	42.928	45.303	46.446	45.249
10.	PP00	511.333	205.117	312.676	335.614	400.101
11.	PPG25	320.833	279.243	109.741	125.291	293.059
12.	PPS25	455.000	199.317	98.911	243.665	181.650

6.4.3 RESULTS FROM PERCENT WEIGHT LOSS DURING SCREENING OF BIODEGRADATION OF SPECIMEN IN OPEN AIR:

Sr.No.	Specimen	Pseudo monas Aeru ginosa	Staphylo coccus	E-Coli	Asper gillus Niger	Rhizo pus	Conso rtium
1.	LD00	20.820	23.000	23.790	25.770	4.970	22.300
2.	LDG25	25.150	25.990	21.780	25.950	6.620	13.120
3.	LDS25	22.690	23.120	24.980	25.570	30.920	5.793
4.	HD00	66.300	58.175	58.130	54.045	28.767	1.640
5.	HDG25	21.640	57.955	55.610	15.670	7.930	15.087

6.	HDS25	26.140	19.860	19.630	21.420	18.860	27.820
7.	PS00	25.250	46.940	54.935	20.510	14.460	19.593
8.	PSG25	23.820	47.720	18.930	20.490	44.405	14.187
9.	PSS25	31.300	27.000	25.380	24.560	27.780	22.667
10.	PP00	70.597	67.930	55.340	53.330	0.790	48.620
11.	PPG25	56.000	55.645	19.280	24.170	4.970	20.240
12.	PPS25	56.945	20.290	21.520	47.093	6.620	55.970

6.4.4 RESULTS FROM PERCENT GROWTH OF MICROORGANISM ON SPECIMEN AFTER 4 WEEKS:

SR. NO.	SPECIMEN	PERCENT GROWTH ON SPECIMEN	COLOUR OF GROWTH	APPARENT MICROORGANISM
1.	LDOO	Growth surrounds the specimen	Yellow spore	Aspergillus niger
2.	LDG25	100%	Black spore	Aspergillus niger
3.	LDS25	100%	Black spore	Aspergillus niger
4.	HDOO	Growth surrounds the specimen	Black spore	Aspergillus niger
5.	HDG25	Growth surrounds the specimen	Grey/dirty greenish	Aspergillus niger/Pennicillium
6.	HDS25	100%	Black spore	Aspergillus niger
7.	PSOO	Growth	Dirty yellow	Aspergillus

		surrounds the specimen		niger/Pennicillium
8.	PSG25	100%	Black spore	Aspergillus niger
9.	PSS25	100%	Dirty yellow	Aspergillus niger/Pennicillium
10	PPOO	Growth surrounds the specimen	White fungal base+ dirty green	Unknown fungi + Aspergillus niger
11	PPG25	Growth surrounds the specimen	Dirty yellow with white spots	Unknown fungi
12	PPS25	100%	Black/brown spore	Aspergillus niger

6.4.5 RESULTS FROM PLANT TOXICITY AND SOIL ANALYSIS:

SOIL PROPERTY	INITIAL VALUE	VALUE AFTER 3 MONTHS	REMARKS
ELECTRICAL CONDUCTIVITY	0.20	0.21	ORGANIC CARBON CONTENT WAS FOUND EXTRAORDINARILY HIGH.
PH	7.7	7.6	
ORGANIC CARBON	0.31	0.95	
P_2O_5	47	44	
K_2O	430	450	

6.5. COST ANALYSIS:

@ 1.67 times material saving can be observed with all combinations of thicknesses because the strength of the film is proportional to the thickness of the film.

Sr. No.	Material	Cost Rs./Kg	Tensile strength kgf/cm²	Film thick ness micron	Material Consu mption Kg/year	Lay flat area m²	Power Consu mption kwh
1.	Virgin	75	56.131	5	108000	22500000	17280
2.	Plasticized	75	69.229	3	108000	37500000	9504
3.	Saving		@ 1.25 times	@ 1.67 times	43200	15000000	7776
4.	Saving in Rupees				108000	Rs.32, 40,000	34992 Rs.4.5/unit
5.	Saving in Rupees				100	Rs.3000	32.4 Rs.4.5/unit

6.6. CONCLUSIONS:

◊The mechanical strength was improved with the use of plasticizers.

◊The specific viscosity reduces with the use of plasticizers.

◊Percent Weight loss between 5-70% was observed in each specimen. The weight loss with Aspergillus Niger as the base microorganism is highest with all specimens.

◊@ 70-99% loss in tensile strength within 12 weeks was observed with plasticized LDPE, HDPE, PS and PP.

◊The loss in percent elongation within 12 weeks of almost all specimens is between 140- 580 during the span of 12 weeks.

◊Loss in specific Viscosity within 12 weeks ranges from 60-600 after 12weeks. The viscosity is reduced gradually.

◊After 12 weeks fragmentation into extremely small pieces of the specimens was observed and all the specimens were mixed up. Hence the loss in mechanical strength and viscosity could not be measured.

◊The structure of Aspergillus fungi was changed depending upon the nutrition available and environmental factors affecting the microorganisms i.e. Aspergillus Niger was formed with LDPE and PS, Aspergillus fumigatus was formed with HDPE, Aspergillus ustus was formed with PP. Also some unidentified fungi have developed.

◊ The films from HDPE, PS and PP could not be produced by the conventional screw extruder. Due to their crystalline nature they could not retain the plasticizer in the polymer matrix. During the extrusion the plasticizer exudes out of the polymer.

◊The plant toxicity test and the soil analysis of LDPE film show the increase in the carbon value of soil from 0.31% to 0.95%. Hence it can be inferred that the degradation of the polymer do not adversely affect the soil or its fertility. With the increase in the carbon content of the soil we can also infer that the residue of the plasticized degraded LDPE films contain carbon structure.

◊Film from LDPE was manufactured on large scale on a conventional screw extruder. Due to the effect of plasticizers on the processing various processing parameters were lowered.

◊@ 1.67 times material saving can be observed with all combinations of thicknesses because the strength of the film is proportional to the thickness of the film.

6.7. FUTURE RESEARCH SCOPE:

◊The effect of specific specie of microorganism on the biodegradation of polymer under contamination free environment can be studied.

◊The biological system affecting the biodegradability of un plasticized specimen can be identified.

◊Procedures for reproducibility of the biological system that affect the biodegradability can be developed.

◊ The path of biodegradation can be studied by the electron microscopy.

◊The mixing device for uniform mixing of plasticizer in the polymer can be designed.

◊Proper additives for the crystalline polymer like HDPE, PS and PP can be identified so that the plasticizer can be retained in the polymer matrix without adversely affecting its biodegradability.

◊Device to measure the precise viscosity of the polymer after subjecting to the microorganism can be designed.

◊Procedure to analyze the biomass-residue from the screening test for biodegradability can be designed so as to identify the composition of the residue.