Conclusion and Recommendations

7.1 Conclusion:

Plastic bags are quiet extensively used by the public additional than any other, mostly due to their cheaper cost and large scale production. It causes various adverse effects on the human and the environment. Therefore, it is imperative to develop efficient, economical and sustainable technique for the degradation of these hazardous pollutants. In this regard, bioremediation has been proposed as the most favourable and sustainable technique. Research communities are increasingly focusing on this technique for the management of polyethylene pollutant from solid waste.

Biodegradation of polyethylene depends mainly on the hydrophobicity of the surface and efficiency of microbes. However, the selection of microorganisms is critical factors in efficient degradation of polyethylene waste. Use of a pure culture system permits the distinction between chemical and biological degradation of a polymer by providing necessary controls and also facilitates the experimental replication needed to obtain statistical evaluation of the data (Hanaa et al. 1998, Lee et al. 1991). So we studied the biodegradation by using pure microbial (bacterial and fungal) culture.

In the present study biodegradation of low density as well as high density polyethylene films by fungal strain R*hizopus oryzae* NS5 and bacterial strain K*lebsiella pneumoniae* CH001 has been done. Different results obtained by evaluation of wt loss, change in pH, tensile strength, contact angle, surface morphology and functional groups have confirmed that *rhizopus oryzae* NS5 utilises LDPE and HDPE as a carbon source for its development. Various parameters have been optimized for the effective biodegradation of films. With an increase in time gap, concomitant increase in percent degradation by

both fungal and bacterial culture was observed. pH is one of the most important factors controlling the growth and enzymatic activities of the microorganisms. In our study, pH 3.0 to 10.0 was selected to observe the HDPE and LDPE degradation efficiency of selected fungal strain. Similarly effect of temperature and agitation speed of rotator shaker was optimized. Effect of temperature and shaking speed was studied in the range of 25 to 50^{o}C and 90 to 150rpm respectively.

Based on the present results following significant conclusions have been drawn.

- The intermediates formed after biodegradation were analysed by GCMS results and the major products were fatty acid (carboxylic acid), plasticizer (dibutyl thalate), benzene, alcohols, ethers and alkanes, alkenes of low carbon chains. Which confirm the biodegradation of long C chain of PE into short C compounds.
- FTIR results of PE films after biodegradation experiments showed peaks in the absorbance range of 3500–3200 cm^{-1} which corresponds to the presence of alcohols, acids and phenols, which are similar to GCMS results indicating that degradation was carried out successfully.
- It was found that *Rhizopus oryzae* NS5 among fungal strains and *Klebsiella pneumoniae* CH001 among bacterial strains were most efficient in biodegradation of PE films.
- *Rhizopus oryzae* NS5 cells are viable only for 30 days while *Klebsiella pneumoniae* CH001 is viable upto the 60 days.
- So biodegradation assay with *Rhizopus oryzae* NS5 was performed for 30 days and with *Klebsiella pneumoniae* CH001 for 60 days time period.
- *Rhizopus oryzae* is more efficient for the degradation of LDPE in comparison to HDPE film.

- *Klebsiella pneumoniae* CH001 is more efficient for the degradation of HDPE in comparison to LDPE film.
- *R. oryzae* degrades 5.9% of HDPE and 8.7% % LDPE in 30 days incubation period.
- *Klebsiella pneumoniae* degrades 18.4% % of HDPE and 8.4% % LDPE in 60 days incubation period.
- We have studied the enzymatic activities of laccase and manganese peroxidase at different time intervals and found that activity of manganese peroxidase is more than laccase.
- Parameters have been optimized for the maximum biodegradation and it has been found that optimum pH, temperature and agitation speed for the *R. oryzae* was found to be 6, 40^{o}C and 120 rpm respectively.
- For *K. pneumoniae* optimum pH, temperature and agitation speed was 6.5, 37 ^{o}C and 110 rpm respectively.
- Biodegradation of recycled polyethylene carry bags has not been performed earlier.
- In the biodegradation study of recycled polyethylene of different grades there was 24.9%, 28.1% and 30% weight loss in gradeI, gradeII and gradeIII polyethylene.
- The degradation mechanism has been proposed to be governed by a series of enzymatic solubilization nevertheless the exact mechanism has not been fully apprehended. These findings are in support of the earlier works on biodegradation of LDPE and HDPE in natural environmental conditions whereas in vitro studies have not been comprehensively investigated. They also furnish novel approaches of putting into effect the plant pathogen for degradation goal over a long term. Thus the data procured is an affirmation of degradation efficiency of the isolated

microorganisms on LDPE and HDPE which can be upgraded further in an industrial scale for degrading various plastic materials .

7.2 Recommendations for Further Studies:

The followings aspects should be considered for further study:

- Development of hybrid pathways through genetic manipulation of microorganisms should be analysed.
- There is a need for much more as well as continuous research to achieve an economical route for the bioremediation of waste virgin polyethylene bags and recycled polyethylene carry bags as compared to existing processes.
- Effect of biosurfactants on biodegradation should be studied by as there is scanty of research.
- Polyethylene carry bags should be blende with photo sensitive metal oxides and biodegradable polymers like starch which get photo degrade in the contact of sunlight and biodegraded easily.
- There is need of more research to understand the effect of polyethylene degradation products on soil microbiology and plant growth.