IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

FEASIBILITY STUDY ON CONVESION PLASTIC WASTE INTO COMPOST GENERATION USING UV-TECHNOLOGY

PRASHANTH S[1]
Civil Engineering
Alva's Institute of Engineering and Technology
Mijar-Moodbidire,

SUHAS K[2]
Civil Engineering
Alva's Institute of Engineering and Technology
Mijar-Moodbidire

VAFA[3]
Civil Engineering
Alva's Institute of Engineering and Technology
Mijar-Moodbidire

1,2,3 UG-Scholar's Department of Civil Engineering AIET-Moodbidire

***Abstract*— Low-density polyethylene (LDPE) breaks down when exposed to ultraviolet (UV) light, but the extent of its deterioration varies under different environmental conditions. This study aimed to examine how LDPE strips change in terms of physical and chemical properties when exposed to aerobic & un-aerobic Conditions, distilled water (DW)+cow dung, and one sugar solution—one combination of cow dung & cow urine and the other cow urine —for 30 days at 30°C. The LDPE samples were analyzed at 7, 14, 21, 28-day intervals for changes in their strength, surface texture, and chemical composition. The results showed that LDPE degraded the most in air, followed by Un-Aerobic. Oxygen was found to be a key factor in speeding up the degradation of LDPE in air.**

Keywords—UV-Technology, LDPE-Ash, Cow-Dung Cow-Urine, Sugar solution.

1. INTRODUCTION .

[1]Plastic waste contributes about 10-13% of the total waste generated worldwide, largely from items like plastic bottles, bags, and containers. Polypropylene (PP) and polyethylene (PE) are the most common types of plastic, with polyethylene further divided into high-density (HDPE) and low-density (LDPE) types. LDPE, which is lightweight and flexible, is widely used for packaging, but its thin, branched structure makes it difficult to recycle and dispose of. Conventional methods of plastic disposal, such as landfilling and incineration, are harmful to the environment, releasing toxic gases or taking hundreds of years to degrade.

Biodegradation offers a promising solution by using microorganisms to break down plastic without producing harmful by-products. Although this process is environmentally friendly, it takes a long time. Pre-treatment methods, such as UV irradiation or chemical treatments, can speed up the degradation process by altering the plastic's surface structure, making it easier for microbes to break down the material. Despite its usefulness, LDPE can degrade when exposed to harsh environmental conditions over time, such as in outdoor weathering. This degradation leads to changes in its mechanical, thermal, and physical properties, which affects its performance in applications like insulation for energy distribution cables. Weathering, especially exposure to sunlight, can cause chemical changes in LDPE, leading to

deterioration. To make LDPE more durable and extend its lifespan, it's essential to understand how it degrades under different environmental conditions.

This study focuses on understanding how pre-treatment, specifically UV irradiation, affects the degradation of LDPE. By analyzing the physical and chemical changes in the plastic, the research aims to demonstrate how pre-treatments can help manage plastic waste more efficiently. Techniques like FTIR (Fourier Transform Infrared Spectroscopy), SEM (Scanning Electron Microscopy), and EDX/EDS (Energy Dispersive X-ray Spectroscopy) are used to observe the changes in the plastic's properties and surface structure after pre-treatment. The study highlights the importance of material characterization and pre-treatment in making plastic degradation more sustainable
.

2. MATERIALS AND METHEDOLOGY

2.1 Sampling and preparation

[2]In this study, samples of low-density polyethylene (LDPE) with different thicknesses were collected. The purpose was to examine how varying thicknesses of these LDPE films affect their properties after certain treatments. Four different thicknesses were chosen: 50 mm, 75 mm, 90 mm, and 100 mm, all with a density of 0.913 g/cm³.

In addition, the samples were cut into strips for mechanical testing, and small portions were used for advanced techniques like SEM (Scanning Electron Microscopy) and FTIR (Fourier Transform Infrared) analysis. These tests helped to observe any changes in the structure of the LDPE films after the pre-treatment processes.

2.2 Materials

[3]**2.2.1 The Polymer**
The polymer used in this study was a type of low-density polyethylene (LDPE). This type of LDPE has a melt flow index (a measure of how easily it flows when heated) of 1.9 g/10 minutes.

2.2.2 Film Composition and Preparation
All films were made by Crude Chemicals in the UK. LDPE masterbatches (mixtures with specific additives) were prepared with a 5% dispersion of ZnO nanoparticles and 2% of a stabilizer called Irganox 1010. This was done by mixing with the Basel LDPE using a twin-screw extruder, where the material was melted at around 180-185°C. The extruded material was cooled in water and cut into pellets. To get the desired ZnO concentration, the pellets were blended back into the same LDPE polymer and shaped into films. The films were then cooled on rollers chilled to 10°C.

To ensure even dispersion of ZnO, a carrier package was added in proportion to the ZnO concentration. Films with 0.25% ZnO were labeled as “Zn-0.25” and those with 0.75% as “Zn-0.75.” Control samples without ZnO were also prepared for comparison.

2.2.3 CO_2 Photogeneration Measurement
CO_2 generation from the films was measured using a specialized cell. Film samples were placed in the cell and held in place by a metal ring. Before starting, the cell was flushed with oxygen at various humidity levels. The cell was then placed in a spectrometer, which measured the CO_2 and water levels. Once stabilized, the film samples were irradiated with light, and the CO_2 increase was tracked using infrared absorption at 2360 cm^{-1}. The tests were highly consistent, showing only slight differences even when the lamp was replaced.

Carbonyl Development and Mass Changes during UV Exposure Films were exposed to UV light (from UVA340 tubes) at 40°C to test for changes in composition. The increase in carbonyl groups (a marker of degradation) was tracked through infrared absorption. Film samples were weighed every 80 hours to check for mass loss, comparing them to control samples kept in the dark to prevent degradation.

2.2.4 Measurement of Average Molecular Weight
To measure changes in the films' molecular weights after UV exposure, high-temperature gel permeation chromatography (HGPC) was used. The films were dissolved in a solvent 1,2,4-trichlorobenzene) and analyzed to determine changes in molecular weight based on a standardized curve for polystyrene.

3. RESULTS:

[4], [5]**3.1 UV and Visible Light Absorption**
The transmission spectra show how much UV and visible light passes through films with different concentrations of ZnO nanoparticles. Films with ZnO absorb more light near 360 nm due to ZnO’s ability to excite electrons, which also gives it photocatalytic properties.

Films with 0.25% ZnO (Zn-0.25) and 0.75% ZnO (Zn-0.75) had absorbances of around 0.45 and 1.01 at 300 nm, meaning the higher ZnO content absorbed more light. This is lower than the absorption levels seen in films with titanium dioxide (TiO_2) nanoparticles.
During UV exposure, all films (with and without ZnO) absorbed more light, especially between 300-360 nm. After exposure, the ZnO and TiO_2 films showed increased absorption around 215-220 nm, 280 nm, and a weak peak near 340-350 nm, suggesting certain chemical changes in the films.

3.2 Carbonyl Group Development (Photostability)
The study used infrared (IR) spectroscopy to track the growth of carbonyl groups (C=O) in the films, as these groups indicate degradation. The IR spectra of unexposed films show little difference when adding the Irganox stabilizer. All films developed new IR absorption peaks after UV exposure, especially at 1711 cm^{-1}, and weaker absorptions around 1728 cm^{-1} and 1780 cm^{-1}, which are typical for carbonyls in different chemical environments. ZnO-containing films showed more absorption around 1713 cm^{-1} and 1737 cm^{-1}, possibly due to esters, along with other peaks indicating chemical changes in the structure. Effect of ZnO on Carbonyl Group Intensity The intensity of the carbonyl absorption (related to film degradation) was measured over UV exposure time. Films with 0.75% TiO_2 had the highest carbonyl absorption, followed by 0.25% TiO_2, 0.75% ZnO, and 0.75%

ZnO with Irganox. The Zn-0.25 film initially had higher carbonyl absorption than the base LDPE, but after prolonged exposure (above 465 hours), it showed less degradation than the base LDPE. This suggests that ZnO initially accelerates degradation but provides more stability over extended exposure. This experiment shows how different concentrations of ZnO influence the film's absorption and degradation under UV exposure, helping understand its potential for use in UV-resistant applications.

[6]**3.3 Film Embrittlement & Weight Loss**

When exposed to UV radiation (UVA 340), all films eventually became brittle and cracked. The timing of cracking and the level of carbonyl absorption (a measure of degradation). Cracks could form at any point in the time leading up to inspection, so the times are approximate. Films containing ZnO gradually lost weight throughout the exposure, suggesting the breakdown of the material into volatile compounds like CO_2 and water. In contrast, films without ZnO (like the parent LDPE and TiO_2/LDPE) initially gained weight, likely due to oxygen being incorporated into the structure. After longer exposure, their weights also decreased. By the end of 580 hours, the weight loss was around 0.40% for the parent LDPE, 1.1%-1.5% for TiO_2 films, and 2.5%-6.2% for ZnO films.

3.4 CO_2 Photogeneration Monitoring

CO_2 generation in the films during UV exposure was tracked, comparing ZnO- and TiO_2-containing films. The order of CO_2 generation was Zn-0.75 > Zn-0.25 > Ti-0.75 > Ti-0.25 > Parent LDPE, meaning ZnO films produced the most CO_2. For ZnO films, the rate of CO_2 generation slowed over time. Between 240 and 340 minutes of exposure, only 30% as much CO_2 was produced as in the first 100 minutes. The amount of CO_2 generated increased with higher humidity, and stacking two Zn-0.75 films doubled CO_2 absorbance compared to a single film.

[7]**3.5 Average Molecular Weight**

The study measured the average molecular weight of films before and after UV exposure (651 hours). The molecular weight distribution widened in the parent LDPE when exposed to UV light, indicating both chain breaking (scission) and linking between chains (crosslinking). Films with ZnO or TiO_2 showed a narrower molecular weight distribution, suggesting more chain scission. ZnO and TiO_2 appear to prevent crosslinking to some extent. The molecular weight data imply that ZnO behaves similarly to TiO_2, though ZnO may result in less size degradation, with more CO_2 generated from terminal ends (ends of polymer chains) rather than side branches, suggesting a specific oxidation pattern with ZnO.

[7]**3.6 Tensile Strength Changes Over Time**

The strength of LDPE (low-density polyethylene) was tested over time as it was exposed to UV light in different environments. Initially, the tensile strength of unexposed LDPE was 23.8 N/mm^2. After 90 days of UV exposure, the strength had significantly decreased, especially in air (7.61 N/mm^2) and DDW (10.53 N/mm^2). The decrease in tensile strength was less in saline solutions, with higher values of 18.74 N/mm^2 in low-salt (0.017 M) and 20.9 N/mm^2 in high-salt (0.6 M) solutions. Stress-strain curves show that after 90 days, the UV-exposed LDPE became brittle, especially in air, where it failed without stretching much, similar to brittle materials.

[7]**3.7 Changes in Young's Modulus**

Young's modulus (a measure of stiffness) was initially 198.4 N/mm^2 for the unexposed LDPE. After 90 days of UV exposure, Young's modulus increased, indicating that the material became stiffer. For instance, LDPE exposed to air had a modulus of 350 N/mm^2, and in DDW, it was 309 N/mm^2. In MSM and saline water, the increase was smaller (249 and 209.47 N/mm^2, respectively). This stiffness increase in air and DDW also made the material more brittle. However, the saline solution's high ionic strength reduced degradation, allowing the LDPE to stay ductile.

[7]**3.8 Physical Observations of LDPE Samples**

Physically, LDPE strips in the saline solution retained their flexibility even after 90 days, while other samples became brittle. This shows that saline environments help protect LDPE from becoming stiff and brittle under UV exposure.

[7]**3.8.1 Reaction Kinetics and Degradation Rate**

The reaction kinetics (rate of degradation) was analyzed to measure the breakdown speed in different conditions. LDPE in air followed first-order kinetics, meaning the degradation rate depended on the material's remaining strength. In DDW, the degradation rate fit a zero-order model, indicating a constant degradation rate over time. For comparison, a first-order reaction rate constant of 0.01 day^{-1} was also considered appropriate for DDW, despite being slightly less accurate than the zero-order model.

4. DISCUSSION:

[6], [8]**4.1 UV Absorption**

ZnO/LDPE films absorb less UV light than TiO_2/LDPE films, as ZnO has a lower absorption rate. When exposed to UV, films absorb more light below 300 nm because of carbonyl groups (compounds indicating degradation), seen through IR measurements. Even though ZnO/LDPE absorbs less, stacking two Zn-0.75 films results in 135% of the CO_2 from a single film. This suggests that the front film absorbs about 65% of UV light, reducing what the rear film absorbs. ZnO's degradation effect likely varies by intensity (I^0.5), similar to TiO_2. Due to lower absorption, ZnO protects the polymer less from UV, so ZnO/LDPE experiences more degradation than TiO_2/LDPE

.

[3], [7]**4.2 Measures of Film Photodegradation**

4.2.1 The Effect of Organic Additives

Adding a small amount of Irganox 1010 (an antioxidant) had minimal impact on initial IR absorption and carbonyl formation, meaning it did little to change degradation. So, the focus remains on the effect of ZnO or TiO_2 nanoparticles.

4.2.2 Film Cracking and Weight Loss

Carbonyl development (signifying degradation) aligns well with how long the films last before cracking, as shown in ZnO-containing LDPE has less carbonyl formation and lasts longer than TiO_2-containing films due to its lower UV absorption.

4.2.3 Photogeneration of Carbon Dioxide

CO_2 generation increases as the amount of ZnO in LDPE films increases. The CO_2 likely results from the film's degradation rather than leftover zinc carbonate. Higher humidity also boosts CO_2 generation, as seen in both ZnO and TiO_2 films.

Interestingly, ZnO/LDPE generates more CO_2 than TiO_2/LDPE despite lower UV absorption. This suggests that ZnO particles trigger oxidation at the ZnO/polymer interface, potentially causing small craters around the particles as seen with TiO_2 in other materials. This contact reduction slows oxidation, leading to the curved CO_2 generation pattern observed over time in Zn-0.75 films a logarithmic trend rather than a simple linear one.

[9]**4.2.4 Relationship of CO_2 Photogeneration with Film Degradation**

In studies comparing films made of ZnO/LDPE and TiO_2/LDPE, CO_2 photogeneration (or the amount of CO_2 produced when exposed to light) showed a strong correlation with weight loss in both types of films. However, the amount of CO_2 produced did not strongly relate to the film's overall lifespan. Although ZnO/LDPE generated more CO_2 than TiO_2/LDPE, ZnO/LDPE showed lower levels of carbonyl group formation, which was surprising. Previous studies with TiO_2 suggested a good relationship between CO_2 production and carbonyl group formation. However, ZnO appeared to inhibit carbonyl growth in LDPE, consistent with findings in earlier studies.

M4.2.5 Analysis of IR Spectra and Chemical Changes in Films

To understand why more CO_2 was generated in ZnO/LDPE, researchers examined infrared (IR) spectra of the films, focusing on the carbonyl region. Carbonyl groups form during degradation, and changes in their IR absorption give clues about the degradation products. The analysis identified peaks associated with specific chemical groups such as ketones, carboxylic acids, and vinyl groups. In ZnO/LDPE films, carboxylic acids and esters formed differently than in TiO_2/LDPE, suggesting ZnO alters the degradation pathway.

4.2.6 Mechanism of Degradation and Impact on Polymer Chain Length

[10]In ZnO/LDPE, CO_2 photogeneration occurs mostly at the ends of polymer chains rather than breaking the chains in the middle. This means that while CO_2 is lost, the molecular weight of the remaining chains decreases less than with TiO_2/LDPE. In studies of high-density polyethylene (HDPE), ZnO had a smaller impact on molecular weight reduction than TiO_2. Thus, ZnO degradation results in a smaller reduction in chain length, helping to maintain some mechanical properties of the polymer.

4.3 Mechanical Properties and Durability

ZnO's unique degradation process—where CO_2 forms at the chain ends rather than breaking the chains—preserves polymer strength better than TiO_2. Consequently, ZnO/LDPE films show longer times to crack and less reduction in tensile strength and elongation. This explains why ZnO was found to degrade mechanical properties slower than TiO_2, even though it causes more weight loss through CO_2 generation.

4.4 FTIR Spectroscopy and Environmental Effects

[2]LDPE (Low-Density Polyethylene) films were tested under UV light for various periods (0, 30, 60, and 90 days) across four different conditions: air, distilled deionized water (DDW), mineral salt medium (MSM), and saline water. Using FTIR (Fourier-Transform Infrared) spectroscopy, new peaks appeared at wave numbers around 3,300 cm^{-1} and 1, indicating the formation of

hydroxyl and carbonyl groups (types of chemical bonds). Peaks at 2,919 cm^{-1}, related to C-H bonds, faded over time, indicating bond breakage under UV light. In MSM and saline water (ionic strengths 0.017 M and 0.6 M), fewer changes in these bonds were observed, suggesting reduced degradation in these environments.

4.5 Degradation Comparison in Different Media

[11]The analysis showed that LDPE deteriorated the most in air due to the higher oxygen levels, which increased photooxidation (a process of degradation due to light and oxygen). In DDW, LDPE also showed significant breakdown with both hydroxyl and carbonyl groups forming, while in MSM, only carbonyl groups formed, indicating less degradation. The presence of salts and minerals in MSM and saline water seems to reduce light penetration, slowing down the degradation process.

4.6 Mechanism of Degradation

UV radiation provides enough energy to break C—C and C—H bonds in LDPE, producing free radicals. These radicals react with oxygen, leading to the formation of hydroxyl and carbonyl groups. This photooxidation process follows several stages, such as chain breaking, branching, and cross-linking, which contribute to LDPE's gradual breakdown under UV exposure.

4.7 Surface Morphology with AFM Analysis

Using Atomic Force Microscopy (AFM), researchers obtained high-resolution 3D images of LDPE films exposed to UV light in air and DDW. The initial LDPE film had a relatively smooth surface. After 90 days of UV exposure, the film's surface showed increased roughness with more peaks and higher peak heights, visible in 3D images, indicating the surface was becoming wavier and rougher over time.

4.8 Surface Roughness Quantification

AFM 2D images further revealed that the surface texture of the UV-irradiated film became rougher. The surface roughness was measured in terms of the average roughness (Ra) and root mean square roughness. For the initial LDPE film, Ra and were 2.7 and 4.0 nm, respectively. After 90 days in air, these values increased significantly to 71.8 and 90.9 nm. The increase in roughness highlights the fractures and holes formed on the film due to the photoinduced reactions under UV light.

[12]4.9 Effects of UV on LDPE in Different Solutions

compared the roughness values of LDPE in DDW, MSM, and saline water. The initial low roughness value was due to the smoothness from the blow-molding manufacturing process. UV light caused noticeable roughening, with the effect more pronounced in air and DDW than in MSM or saline water. This roughness is caused by the film breaking down and forming cracks under the intense energy of UV light.

5. CONCLUSION

This study looked at how UV radiation affected LDPE (low-density polyethylene) film over 90 days in four different environments: air, double distilled water (DDW), mineral salt media (MSM), and saline water. Here are the main findings:
1.Chemical Changes: FTIR analysis showed that after 90 days of UV exposure, LDPE films in air and DDW developed new absorbance peaks, indicating the formation of hydroxyl (OH) and carbonyl (C=O) groups. These changes suggest that photooxidation (degradation due to light) occurred. The most significant degradation happened in air, followed by DDW, MSM, and saline water.
2. Surface Roughness: The roughness of the LDPE film increased significantly from an initial value of 2.7 nm to 71.8 nm after 90 days of UV exposure in air. This roughness increase was caused by damage to the film's surface, resulting in fractures and holes.
3. Surface Damage: Scanning Electron Microscopy (SEM) images revealed cracks, flakes, and pits on the LDPE film's surface due to chemical weathering. Such damage makes plastics more vulnerable to breaking down further in natural conditions, leading to microplastics.
4. Impact of Oxygen: The greatest degradation occurred in the air environment, showing that the presence of oxygen is crucial for initiating the breakdown of LDPE film under UV light.
5. Strength Loss: LDPE films in air and DDW lost strength quickly compared to those in saline solutions, indicating that the open environment (air) and DDW are harsher on the plastic. The highest degradation rates were found in air (0.016 day^{-1}) and DDW (0.01 day^{-1}), while no degradation occurred in the low- and high-salt solutions.
6. Increased Stiffness: The Young's modulus (a measure of stiffness) increased most in LDPE films exposed to air, followed by DDW and low-salinity solutions. There was no noticeable change in stiffness for films in high-salinity solutions (0.6 M), highlighting how salt helps protect these plastic films from UV damage.

Acknowledgment

We would like to extend our sincere appreciation to the authors of the papers we reviewed in this study. Your research has been invaluable in shaping our understanding of the topic and has greatly contributed to this work. Thank you for your dedication to advancing knowledge in this field.

References

[1] V. P. Ranjan and S. Goel, "Degradation of Low-Density Polyethylene Film Exposed to UV Radiation in Four Environments," 2019, doi: 10.1061/(ASCE).

[2] R. L. Kovács *et al.*, "Surface characterization of plasma-modified low density polyethylene by attenuated total reflectance fourier-transform infrared (ATR-FTIR) spectroscopy combined with chemometrics," *Polym Test*, vol. 96, Apr. 2021, doi: 10.1016/j.polymertesting.2021.107080.

[3] R. V. Moharir and S. Kumar, "Structural characterization of LDPE films to analyse the impact of heavy metals and effect of UV pre-treatment on polymer degradation," *J Clean Prod*, vol. 298, May 2021, doi: 10.1016/j.jclepro.2021.126670.

[4] A. Sabei *et al.*, "Biodegradation of UV light treated plastic waste using local bacterial isolates," *Pollution*, vol. 10, no. 1, pp. 404–413, Jan. 2024, doi: 10.22059/POLL.2024.364793.2056.

[5] S. Kumar Sen and S. Raut, "Microbial degradation of low density polyethylene (LDPE): A review," 2015, *Elsevier Ltd*. doi: 10.1016/j.jece.2015.01.003.

[6] R. Yang, P. A. Christensen, T. A. Egerton, and J. R. White, "Degradation products formed during UV exposure of polyethylene-ZnO nano-composites," *Polym Degrad Stab*, vol. 95, no. 9, pp. 1533–1541, Sep. 2010, doi: 10.1016/j.polymdegradstab.2010.06.010.

[7] A. K. Rodriguez, B. Mansoor, G. Ayoub, X. Colin, and A. A. Benzerga, "Effect of UV-aging on the mechanical and fracture behavior of low density polyethylene," *Polym Degrad Stab*, vol. 180, Oct. 2020, doi: 10.1016/j.polymdegradstab.2020.109185.

[8] M. Liu, A. R. Horrocks, and M. E. Hall, "Correlation of physicochemical changes in UV-exposed low density polyethylene films containing various UV stabilisers," 1995.

[9] D. Wang *et al.*, "Degradation mechanism and properties of debris of photocatalytically degradable plastics LDPE-TiO2 vary with environments," *Polym Degrad Stab*, vol. 195, Jan. 2022, doi: 10.1016/j.polymdegradstab.2021.109806.

[10] M. Liu, A. R. Horrocks, and M. E. Hall, "Correlation of physicochemical changes in UV-exposed low density polyethylene films containing various UV stabilisers," 1995.

[11] A. L. Andrady, K. Lavender Law, J. Donohue, and B. Koongolla, "Accelerated degradation of low-density polyethylene in air and in sea water," *Science of the Total Environment*, vol. 811, Mar. 2022, doi: 10.1016/j.scitotenv.2021.151368.

[12] V. P. Ranjan and S. Goel, "Degradation of Low-Density Polyethylene Film Exposed to UV Radiation in Four Environments," 2019, doi: 10.1061/(ASCE).