Introduction

Plastic pollution remains one of the most pressing environmental challenges of the 21st century. Among the various types of plastics, polyethylene terephthalate (PET) is one of the most widely used materials in packaging, textiles, and consumer products due to its durability, chemical stability, and resistance to degradation. However, these same properties hinder its breakdown in natural environments, allowing PET waste to persist for decades (Sui et al., 2023). Improper disposal of PET plastics, particularly in terrestrial ecosystems, has been linked to negative ecological impacts such as disruption of soil microbial communities, altered soil structure, and reduced fertility (Huo et al., 2022).

Conventional plastic waste management practices, including landfilling and incineration, are becoming increasingly unsustainable due to space limitations, greenhouse gas emissions, and the release of toxic by-products (Akram et al., 2024). In the Philippines, weak waste collection systems and low recycling participation further exacerbate this issue, resulting in large amounts of PET waste accumulating in soil environments (Coracero et al., 2021). These challenges have intensified the search for effective, low-cost, and environmentally friendly methods to accelerate plastic degradation.

One promising approach is photodegradation through ultraviolet (UV) radiation. Studies have shown that UV-B and UV-C radiation can induce photo-oxidative reactions that disrupt the polymer backbone of PET, making it more susceptible to degradation (Burrows et al., 2024). However, in real-world soil environments, UV exposure is often limited by shading, soil cover, and fluctuating environmental conditions, significantly reducing its effectiveness.

Alternatively, chemical oxidation methods have gained attention as potential plastic degradation strategies. Potassium permanganate ($KMnO_4$) is a strong oxidizing agent commonly used in soil and water remediation to degrade organic contaminants. Recent studies suggest that $KMnO_4$ may also oxidize PET polymers, increasing surface roughness, introducing oxygen-containing functional groups, and enhancing susceptibility to hydrolytic and microbial degradation (Zhang & Dong, 2019). Compared to UV exposure, chemical treatment may be more practical under soil conditions, particularly where light availability is inconsistent.

Despite the potential of both UV exposure and $KMnO_4$ oxidation, limited empirical research has compared their effectiveness under soil burial conditions. Soil is a complex environment influenced by moisture, microbial activity, pH, and organic content, all of which can affect degradation outcomes. Understanding how these treatments perform within such conditions is essential for developing realistic and scalable plastic degradation strategies. This study addresses this gap by comparing UV-B pretreatment and $KMnO_4$ oxidation at varying concentrations under controlled soil burial conditions, with the goal of identifying a feasible and effective approach for enhancing PET degradation, particularly in resource-limited settings.

Statement of the Problem

This study investigates the effects of potassium permanganate ($KMnO_4$) oxidation and ultraviolet-B (UV-B) light exposure on the degradation behavior of polyethylene terephthalate (PET) plastics under soil-based environmental conditions. Specifically, it seeks to answer the following questions:

1. What are the comparative degradation rates of PET plastics treated with different concentrations of potassium permanganate (0.01 M,

0.05 M, and 0.10 M) after five weeks of soil burial, as measured by percentage weight loss?

2. Is there a statistically significant difference in the degradation rates of PET plastics among the three potassium permanganate concentrations across the five-week monitoring period?
3. Is there a statistically significant difference in the degradation rates between PET plastics treated with potassium permanganate and those exposed to UV-B lamp irradiation prior to burial?

Theoretical Framework

This study is grounded in two interrelated scientific theories: chemical degradation theory and photodegradation theory. These theories explain how polymer materials such as PET undergo structural changes when exposed to chemical oxidants or ultraviolet radiation, leading to accelerated degradation.

Chemical degradation theory posits that polymers can be broken down through reactions initiated by strong oxidizing agents. Potassium permanganate ($KMnO_4$) facilitates this process by attacking ester bonds within the PET polymer chain, introducing polar functional groups that increase hydrophilicity and susceptibility to environmental degradation (Gewert et al., 2015). These chemical modifications enhance further breakdown through hydrolytic and microbial processes commonly present in soil environments.

Photodegradation theory explains how ultraviolet radiation, particularly UV-B (280–315 nm), induces photo-oxidation, free radical formation, and chain scission within polymer structures. These reactions reduce molecular weight and weaken the structural integrity of PET, making it more prone to fragmentation and subsequent degradation (Krause et al., 2020). Environmental factors such as oxygen availability, temperature, and microbial activity may further accelerate these processes (da Costa et al., 2020).

Together, these theories support the assumption that external chemical and physical treatments can enhance PET degradation beyond natural environmental exposure.

Conceptual Framework

The conceptual framework illustrates the relationship between the independent variables, treatment methods, and the dependent variable. The independent variables include potassium permanganate treatment at three concentrations (0.01 M, 0.05 M, and 0.10 M) and UV-B lamp exposure applied as a pretreatment. The dependent variable is the degradation rate of PET plastics, measured by percentage weight loss after soil burial.

Both treatments act through distinct degradation pathways. $KMnO_4$ chemically alters the PET surface, increasing susceptibility to microbial attack, while UV-B radiation initiates polymer chain scission that weakens structural integrity. Soil factors such as microbial activity, moisture, and temperature act as facilitating conditions that influence the overall degradation process. This framework guides the comparison of treatment effectiveness under realistic soil conditions.

Methodology

Research Design

This study employed an experimental research design to assess and compare the effectiveness of ultraviolet-B (UV-B) light exposure and potassium permanganate ($KMnO_4$) oxidation on the degradation of polyethylene terephthalate (PET) plastics under soil burial conditions. An experimental design was appropriate because the study involved the deliberate manipulation of

treatment variables and the measurement of their effects on PET degradation while controlling other conditions.

Five treatment groups were established: (1) a control group with no pretreatment, (2) a UV-B light exposure group, and (3–5) three $KMnO_4$ treatment groups with concentrations of 0.01 M, 0.05 M, and 0.10 M. Each treatment group consisted of eight PET samples, resulting in a total of 40 samples. All samples were buried under identical soil conditions to ensure comparability across treatments.

The independent variable was the type and concentration of pretreatment applied to the PET plastics, while the dependent variable was the rate of PET degradation, operationally defined as percentage weight loss. Degradation was monitored weekly over a five-week soil burial period. This repeated-measures approach allowed for the observation of degradation trends over time and strengthened the reliability of treatment comparisons.

Sampling Technique

This study did not involve human participants. Purposive sampling was used to select PET materials to ensure consistency and relevance to real-world plastic waste. Post-consumer PET bottles (Coke Mismo) were purchased from a local junk shop to represent commonly discarded PET plastics found in terrestrial environments.

The bottles were thoroughly washed with soap and water, air-dried, and cut to remove the neck and base. Only the middle cylindrical portion was retained to ensure uniform material composition. This portion was opened and cut into uniform squares measuring 2 × 2 inches using a ruler as a guide. Each PET piece was air-dried, labeled, and stored in a clean container prior to treatment.

Five groups were formed: one control group, one UV-B treatment group, and three $KMnO_4$ treatment groups. Analytical-grade $KMnO_4$ crystals were dissolved in distilled water to prepare 0.01 M, 0.05 M, and 0.10 M solutions. The required mass of $KMnO_4$ was calculated using the molarity equation:

$$\text{Mass (g)} = M \times V \times MW$$

where MW is the molecular weight of $KMnO_4$ (158.04 g/mol). For one liter of solution, 1.58 g, 7.90 g, and 15.80 g of $KMnO_4$ were used for the 0.01 M, 0.05 M, and 0.10 M concentrations, respectively. Volumetric glassware was used to ensure accuracy.

PET samples assigned to $KMnO_4$ treatments were immersed in their respective solutions for 50 minutes at 60 °C with continuous stirring prior to burial. This soaking procedure was intended to enhance surface oxidation and promote susceptibility to degradation. These concentrations were selected because they are strong enough to act as oxidizing agents without interfering with experimental feasibility.

Soil used for burial was loam soil collected from a single site and homogenized to reduce variability. The soil was distributed into five-inch-diameter pots, each containing one kilogram of soil. Baseline soil organic matter content was estimated using a simplified loss-on-ignition method by heating pre-weighed air-dried soil samples at approximately 360 °C for two hours. While natural variability from microorganisms was acknowledged, using a composite soil batch ensured that all PET samples experienced comparable burial conditions.

Research Instruments

The primary research instrument was a precision digital weighing scale, used to measure the initial and final weights of PET samples. Accurate mass

measurement was essential because degradation was quantified solely through percentage weight loss. The scale was calibrated before each weighing session to ensure measurement validity and reliability.

Treatment instruments included a UV-B lamp emitting wavelengths of 280–315 nm, positioned 20 cm above the samples to provide consistent exposure. Timers were used to regulate UV exposure at six hours per day for seven consecutive days prior to burial. For chemical treatments, volumetric glassware such as beakers and graduated cylinders was used to prepare $KMnO_4$ solutions accurately. Heating equipment maintained the $KMnO_4$ soaking temperature at 60 °C.

Each PET sample was placed inside a permeable nylon mesh pouch with a pore size of approximately 0.5–1.0 mm. These pouches allowed soil water, gases, and microorganisms to interact with the PET while enabling retrieval without loss of material. Additional materials included planting pots, labels, rulers, laboratory ovens, and personal protective equipment (gloves, goggles, masks, and lab coats).

Chemical waste from $KMnO_4$ treatments was neutralized using sodium bisulfite prior to disposal. The reducing agent was added slowly until the solution's purple color disappeared, indicating complete reduction of permanganate ions. Neutralized waste was disposed of following standard laboratory safety protocols.

Data Analysis

The primary data collected consisted of the percentage weight loss of PET samples over the five-week burial period. Measurements were taken weekly, producing five repeated observations per sample. Percentage weight loss was calculated using the formula:

$$\text{Percentage Weight Loss (\%)} = (\text{Initial Weight} - \text{Final Weight}) / \text{Initial Weight} \times 100$$

Data were analyzed using repeated-measures analysis of variance (ANOVA) to determine whether statistically significant differences existed among treatment groups across time. This method was appropriate because the same samples were measured repeatedly at fixed intervals, resulting in correlated observations.

Prior to analysis, assumptions of normality, homogeneity of variances, and sphericity were tested using the Shapiro–Wilk test, Levene's test, and Mauchly's test, respectively. When violations of sphericity were detected, Greenhouse–Geisser corrections were applied to adjust the degrees of freedom and maintain statistical validity.

In addition to significance testing, effect sizes were reported using partial eta-squared to assess the magnitude of treatment effects. Trend analysis was conducted to evaluate whether PET degradation followed linear or nonlinear patterns over the five-week period. All statistical tests were conducted at a 0.05 level of significance, ensuring that observed differences were unlikely to be due to chance.