

The potential of indigenous bacteria from Manado Bay, Indonesia, in biodegrading low-density polyethylene

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Abstract. Plastics are typically composed of low-density polyethylene (LDPE), which significantly contributes to environmental issues, particularly in marine ecosystems. The persistence of plastics poses a significant concern, while the increasing demand for plastic products has exacerbated the challenge of managing plastic waste, ultimately contributing to plastic pollution. This study aims to isolate indigenous bacteria from Manado Bay that have the potential to degrade LDPE plastics. In this study, 12 indigenous bacterial strains were successfully isolated. Six of them demonstrated the ability to grow on selective media containing polyethylene as the sole carbon source, showing polyethylene degradation indicated by the formation of clear zones around the colonies. Isolates MB5, MB7, and MB11 exhibited the largest clear zones and demonstrated potential for LDPE degradation, as indicated by a reduction in the dry weight of LDPE plastic sheets: 3.5461% for MB5, 1.600% for MB7, and 2.0689% for MB11 after 30 days of incubation. Molecular identification revealed that MB5 had 100% similarity with *Stenotrophomonas* sp., MB7 had 100% similarity with *Bacillus cereus*, and MB11 had 99% similarity with *Photobacterium ganghwense*. These findings suggest that these bacterial species have the potential to biodegrade LDPE plastic waste in natural environments.

Key words: *B. cereus*, biodegradation, low-density polyethylene, *P. ganghwense*, *Stenotrophomonas* sp.

Introduction. Plastic is a lightweight and inexpensive material, making it widely used for various human needs, such as household items, industrial products, and trade. One of the most used types of plastic is low-density polyethylene (LDPE), which is mainly used for single-use packaging. As a result, its use generates high levels of plastic waste, posing a significant threat to environmental sustainability (Kibria et al 2023), since plastic is difficult to degrade, leading to accumulation in the environment.

Indonesia is one of the largest plastic-producing countries and ranks as the fourth-largest contributor to plastic waste annually (Benson et al 2021). This plastic waste can enter the marine environment and pollute ocean waters. Plastic waste in marine waters is generally caused by anthropogenic activities on land, which then flows into the ocean through rivers (Jambeck et al 2015; Lebreton et al 2017), potentially altering the quality of marine ecosystems (Wright & Kelly 2017). Manado Bay in North Sulawesi is a marine area that is vulnerable to plastic waste pollution due to inputs from rivers and extensive human activities in the surrounding area.

Plastic wastes decompose into microplastics, which are problematic in aquatic environments due to their persistence and the toxic, often carcinogenic chemicals they may contain. Additionally, microplastics disrupt the balance of marine ecosystems, can enter the food chain through ingestion (Andrady 2017), and pose risks to both environmental and human health (Lalrinfela et al 2024).

The management of plastic waste in the environment has been extensively studied from physical and chemical perspectives; however, microbiological approaches remain underutilized, despite their potential to be more effective and environmentally friendly. Bioremediation is a microbiological method that employs microbes to restore polluted natural environments to their original state (Tatar 2018). In bioremediating plastic waste,

indigenous bacteria - organisms that naturally inhabit or originate from the environment in which they are found - can be utilized (Mareddy 2017), especially those from polluted areas.

Indigenous bacteria can adhere to plastic, making it their new habitat, where they then begin colonizing the surface. The bacterial colonization of plastic waste in aquatic environments is influenced by geographic location and various factors, such as environmental conditions (including nutrient availability and exposure duration), polymer type, biogeography, and seasonal variability (Jiang et al 2018).

Microbial biofilm formation occurs faster in tropical waters than in subtropical waters (Schlundt et al 2020). Additionally, tropical regions exhibit the highest levels of biodiversity. Understanding the biodiversity of indigenous bacteria attached to plastic in tropical regions can serve as a valuable resource in efforts to address massive plastic pollution. However, studies in tropical regions are fewer compared to those in other areas. Research on bacterial biodiversity in marine plastic debris has been largely limited to the Northern Hemisphere, including subtropical and temperate regions (Roager & Sonnenschein 2019). Therefore, this study aims to isolate indigenous bacteria from the waters of Manado Bay, North Sulawesi - a tropical marine area, test their potential for plastic degradation, particularly LDPE types, and identify the bacterial species involved. It is hoped that this research will uncover new local sources and bacterial strains with potential for plastic degradation. This finding could be useful in developing a coastal protection program related to plastic pollution control.

Material and Method

Sampling. The present study was carried out between May and November 2024. A seawater sample was taken from the marine waters of Manado Bay (Figure 1) at locations with significant plastic wastes, some of which were beginning to degrade or disintegrate. One litre of water was collected using a sterile sample bottle. The water sample in the bottle was then placed in a cooler box and transported immediately to the laboratory for further analysis. During the sampling, water quality parameters, including temperature and salinity, were measured at the sampling site.

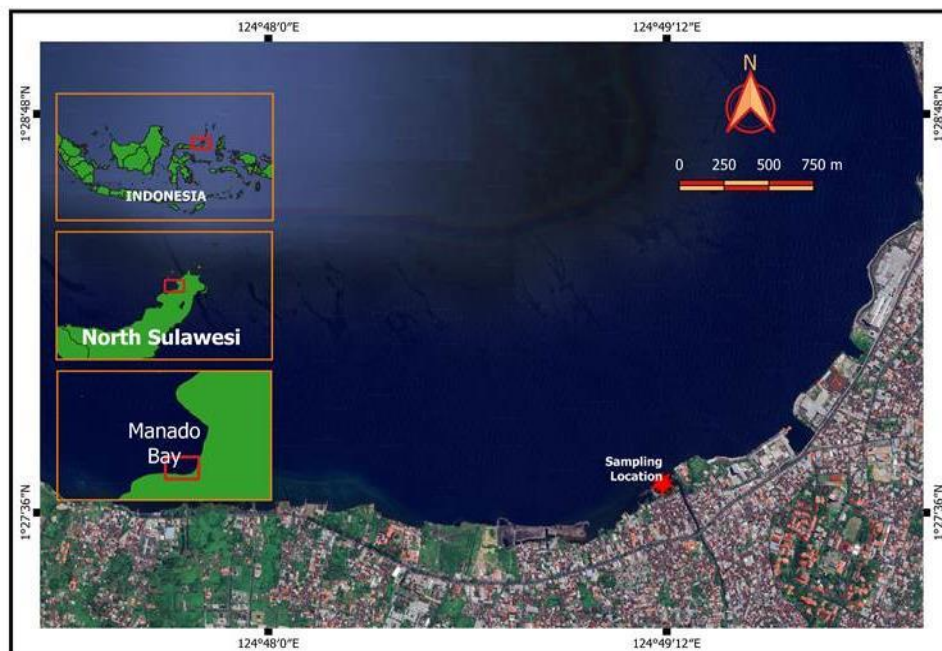


Figure 1. Sampling location, Manado Bay, North Sulawesi, Indonesia.

Culture and isolation of indigenous bacteria. Indigenous bacteria in the seawater were cultured using Nutrient Broth (NB) medium. Bacteria that grew in the NB medium after incubation for 24-48 hours at 30°C were isolated on a Nutrient Agar (NA) medium using

the spread plate method, preceded by serial dilution with phosphate buffer. The culture medium was then incubated at 30°C for 24 hours, after which bacterial growth was observed. Bacteria were cultured at 30°C to match the sampling location's temperature. If a single colony had not formed, the bacteria were subcultured again on NA medium using the quadrant streak method repeatedly until a single colony was obtained. For each single colony that grew, morphological characteristics, such as colony shape, elevation, edges, and colour, were observed.

Second bacterial screening for LDPE degradation. Each single colony was streaked onto NA containing 2% polyethylene glycol (PEG) powder as a carbon source and 0.1% Tween 80 to optimize the biodegradation process (Mukamto et al 2015). The plates were then incubated at 30°C for 48 hours (Edmund Bühler, Netherlands). After incubation, bacterial growth was observed on the culture plates. Bacterial isolates that exhibited growth on NA supplemented with 0.1% LDPE powder were considered positive. Conversely, bacterial isolates that showed no growth or slow growth (where microbial growth on NA containing 0.1% LDPE powder after 48 hours is classified as slow growth) were considered negative.

Testing the biodegradation potential of indigenous bacteria on plastic. Bacteria that grow on NA medium supplemented with 0.1% LDPE powder were then subcultured onto NA medium with the same supplementation but with the addition of 0.02% Congo Red dye. The cultures were incubated for 24-48 hours at 30°C. The formation of a clear zone around the bacterial colony was observed. Colonies that formed a clear zone were then streaked again on NA medium supplemented with 0.1% LDPE powder and 0.02% Congo Red dye and incubated for 24-48 hours at 30°C. The clear zone surrounding each colony was measured to assess the extent of degradation (Rachmawati et al 2021).

The three bacterial isolates with the largest clear zone diameters were then selected for the biodegradation test. A plastic biodegradation test was conducted to determine the percentage reduction in LDPE plastic (obtained from commercial market bags in Indonesia) due to bacterial degradation. The steps of the plastic biodegradation test were as follows: a 1 cm × 1 cm LDPE plastic sample was initially weighed, washed with sterile distilled water, and sprayed with 70% alcohol. The plastic sample was then aseptically placed into a 250 mL Erlenmeyer flask containing 50 mL of NB medium. Two rounds of bacterial isolates were inoculated into the medium. As a control, the medium in a 250 mL Erlenmeyer flask containing LDPE plastic pieces was not inoculated with bacterial isolates. All media were then incubated in a water bath shaker at 100 rpm and 30°C for 30 days. After 30 days, the plastic samples were washed with sterile distilled water, sprayed with 70% alcohol, air-dried, and then weighed using an analytical balance. The percentage of plastic degradation by indigenous bacteria was calculated using the formula (Lou et al 2020):

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Identification of the bacteria. The three bacterial isolates with the largest clear zone diameters were identified through molecular analysis. Genomic DNA was isolated using the QIAprep Miniprep Kit (Qiagen, Hilden, Germany) and used as a template for amplifying the 16S rRNA gene region via PCR. Amplification was carried out with a universal primer pair from Integrated DNA Technologies (IDT, Singapore): 8F (5'-AGAGTTTGATCCTGGCTCAG-3') and 1492R (5'-TACCTTGTTACGACT-3'). PCR conditions included an initial denaturation at 95°C for 6 minutes, followed by 35 cycles of denaturation at 95°C for 30 seconds, annealing at 52°C for 30 seconds, and extension at 72°C for 30 seconds, with a final extension at 72°C for 10 minutes. The size of the PCR products was confirmed by electrophoresis on a 1% agarose gel, with a 1 kb DNA ladder (Solis BioDyne, Estonia) used as the molecular marker. The amplified products were subsequently sent to First-Base Co. (Selangor, Malaysia) for sequencing. The sequence quality was evaluated using Sequence Scanner version 2.0 (Applied Biosystems, USA). Raw sequence traces were trimmed, assembled, and manually curated using Geneious Prime version 2020

(<http://www.geneious.com>). The resulting sequences were then subjected to BLAST analysis against the 16S rRNA gene database at the National Center for Biotechnology Information (NCBI, <https://www.ncbi.nlm.nih.gov/>). Finally, a phylogenetic tree was constructed using the neighbour-joining method in MEGA version 11.

Results and Discussion. The colonies that grew on the selective medium yielded in 12 bacterial isolates with variations in colour, edge, shape, and elevation. These differences in growth forms suggest that the isolates represent distinct bacterial species.

The bacteria were cultured on a selective medium containing PEG. Seven out of the twelve isolates (MB2, MB4, MB5, MB7, MB8, MB9, and MB11) formed clear zones around their colonies when grown on a selective medium containing polyethylene and Congo Red. The presence of these clear zones indicated that the isolates had the ability to degrade polyethylene in the medium. The average diameter of the clear zones ranged from 0.8 to 2.1 cm. Three bacterial isolates exhibited the largest clear zones: MB5 (1.8 cm), MB7 (0.8 cm), and MB11 (2.1 cm) (Figure 2). These isolates are believed to have the capability to utilize polyethylene as their primary carbon source.

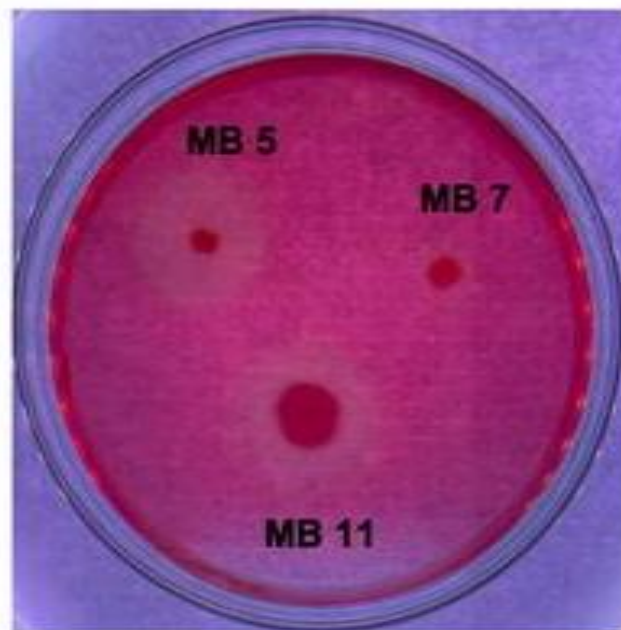


Figure 2. Confirmation test for polyethylene degradation by MB5, MB7, and MB11 using the clear zone method.

Three isolates exhibited the largest clear zone diameters and were subsequently tested for their ability to degrade LDPE plastic. A significant reduction in the dry weight of LDPE plastic sheets was observed, with reductions of 3.5461% for MB5, 1.600% for MB7, and 2.0689% for MB11, while the control showed a reduction of 0.7874% after 30 days of incubation. The control culture medium remained clear, indicating no bacterial growth and suggesting that there was no contamination in the experiment. The decrease in plastic weight in the control could be attributed to friction between the plastic film and the container. However, the weight reduction in the control was still lower than that observed in the bacterial isolates. The reduction in the dry weight of plastics caused by bacterial isolates MB5, MB7, and MB11 may result from intercellular communication among polyethylene-degrading bacterial cells, a process known as quorum sensing (Mukherjee & Bassler 2019).

These results also suggest that the three isolates can utilize polyethylene as a carbon source for survival. When bacteria are cultured for 30 days, they experience carbon depletion in the growth medium and enter a stressed state. Upon the introduction of polyethylene as a carbon source, the bacteria adhere to it, form a biofilm on its surface, and utilize it as an energy source (Ji et al 2024).

Bacteria employ multiple mechanisms to utilize polyethylene as a carbon source. Initially, they attach to the polyethylene surface and develop a biofilm. A biofilm is a structured community of microorganisms, including bacteria, that thrive and reproduce collectively as a colony (Sharma et al 2023). The formation of this biofilm serves as a natural strategy for polyethylene-degrading bacteria to enhance their protection in harsh environments (Shemesh et al 2010). This biofilm is also believed to facilitate the aggregation of polyethylene particles into clusters, potentially affecting measurement accuracy. The second mechanism involves depolymerization, wherein bacteria cleave the C–C bonds in polyethylene, producing shorter polymer chains that dissolve in water and pass through a semi-permeable membrane. Throughout this process, bacteria metabolize the degraded polyethylene as a carbon and energy source, marking the biodegradation stage. The third mechanism consists of assimilation and mineralization (Bagheri et al 2017).

The 16S rRNA genes of MB5, MB7, and MB11 were successfully amplified, with DNA bands appearing at approximately 1500 bp (Figure 3). The amplification of the 16S rRNA sequences resulted in ~1500 bp amplicons (Ginting et al 2019; Wullur et al 2020; Ginting et al 2021). Based on the 16S rRNA gene sequence data from the bacterial isolates, analysed using the rRNA type strains/prokaryotic 16S ribosomal RNA database in NCBI, MB5 showed a close relationship to *Stenotrophomonas* sp. (100% similarity), MB7 to *Bacillus cereus* (100%), and MB11 to *Photobacterium ganghwense* (99%). Similar results were observed in the phylogenetic analysis, as shown in the phylogenetic tree (Figure 4). This analysis indicated that MB5 and *Stenotrophomonas* sp. clustered within the same group, leading to its designation as *Stenotrophomonas* strain MB5. Likewise, MB7 and *Bacillus cereus* formed a single group, resulting in its designation as *Bacillus* strain MB7. Furthermore, MB11 and *Photobacterium ganghwense* were grouped together, leading to its designation as *Photobacterium* strain MB11.

Stenotrophomonas sp. is known for its ability to produce poly- β -hydroxybutyrate (PHB)-degrading depolymerase enzymes. *Stenotrophomonas* sp. isolated from soil samples collected at plastic-contaminated sites, exhibited robust growth in minimal salt medium (MSM) and formed a 4.2 mm hydrolysis zone on MSM supplemented with PHB as the sole nutrient source (Wani et al 2012). Moreover, *S. maltophilia* PRS8 isolated from landfill soil, demonstrated the ability to degrade polyethylene terephthalate (PET) (Din et al 2023), while *S. pavanii* JWG-G1 was able to utilize PET as the sole carbon source through a novel stepwise screening and verification strategy (Huang et al 2022).

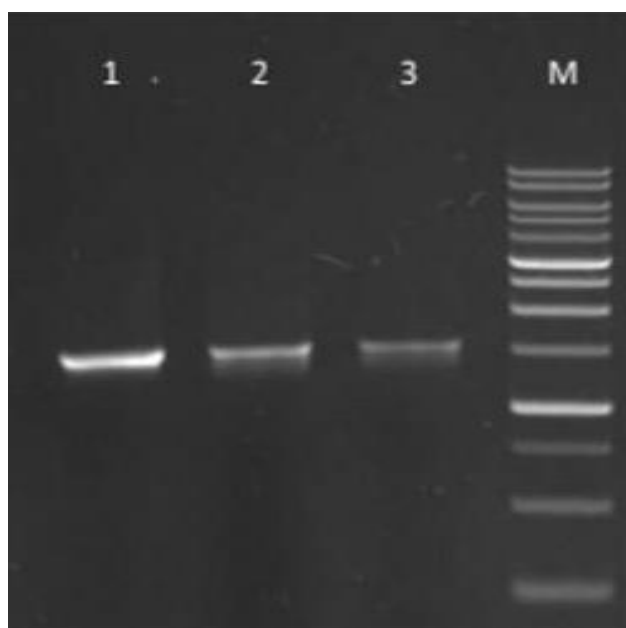


Figure 3. Agarose gel electrophoresis (1%) of the 16S rRNA gene PCR products from bacterial strains MB5, MB7, and MB11 was performed.

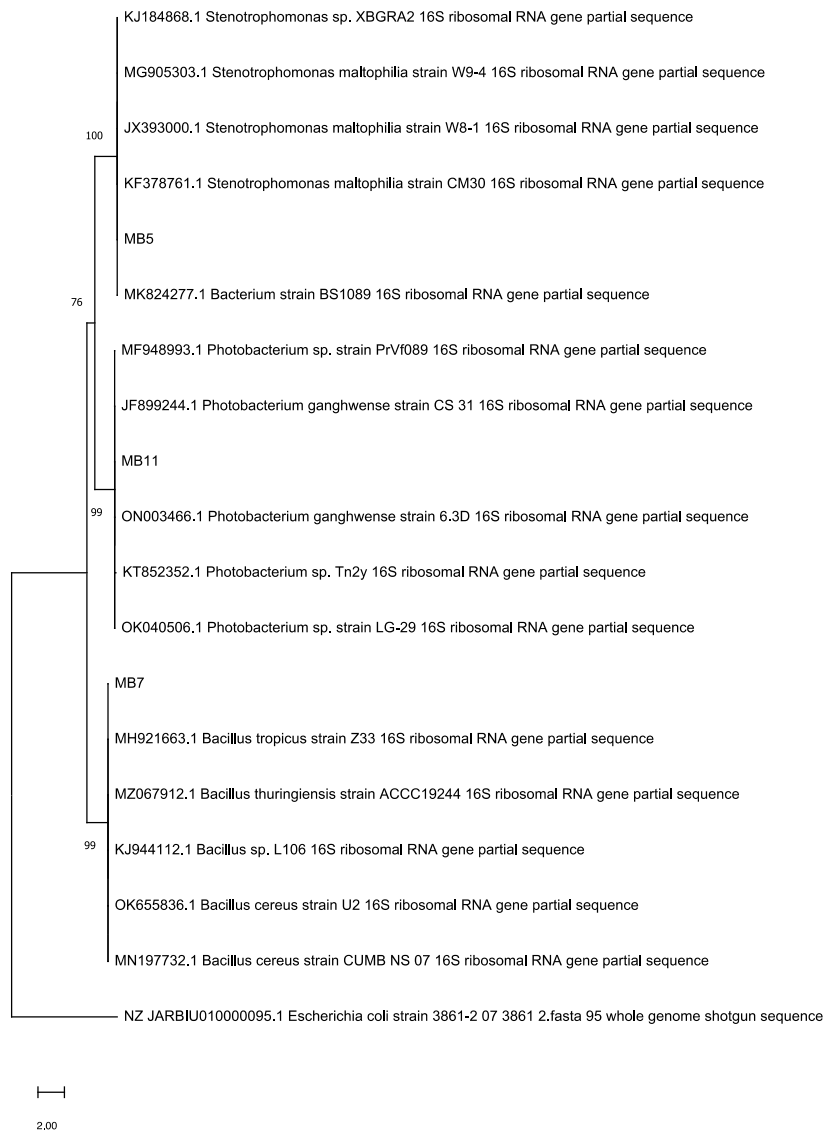


Figure 4. A phylogenetic tree was constructed using the neighbour-joining method based on the 16S rRNA gene sequence analysis of bacterial strains MB5, MB7, and MB11. *Escherichia coli* was used as the outgroup. Bootstrap values, expressed as a percentage of 1,000 re-samplings of the neighbour-joining dataset, were calculated to estimate the reliability of the phylogenetic tree reconstruction.

Bacillus has been shown to degrade LDPE, as evidenced by the reduction in LDPE weight. This is indicated by a decrease in the percentage of the initial plastic weight compared to the final weight after incubation with the bacteria for 30 days on a shaker at 150 rpm and room temperature (Fibrianti et al 2021). Furthermore, *B. cereus*, isolated from a plastic-polluted tropical coastal environment, has demonstrated the ability to degrade LDPE. Scanning electron microscopy (SEM) images of LDPE films treated with *B. cereus* reveal significant surface erosion and visible cracks. Energy-dispersive X-ray (EDX) analysis revealed an increased carbon content and the presence of oxygen in the treated films. Additionally, attenuated total reflectance Fourier-transform infrared (ATR-FTIR) spectroscopy showed characteristic peaks corresponding to specific functional groups, with noticeable shifts observed in the spectra of *B. cereus*-treated samples. A marked increase in carbonyl, internal double bond, and vinyl indices is observed across all treatment groups. Additionally, a decrease in crystallinity is evident in the treated LDPE film (Jebashalomi et al 2024).

P. ganghwense has the potential to produce bioplastic compounds, such as polyhydroxyalkanoate (PHA), which can serve as an alternative to conventional plastics due to their biodegradability. Under suitable conditions, *P. ganghwense* can synthesize PHA from carbon sources like crude glycerol derived from biodiesel production (Lascu et al 2021), demonstrating metabolic capabilities relevant to the bioplastics industry. However, there is no specific research on *P. ganghwense* as a plastic degrader, particularly for LDPE. Most studies still focus on bacteria such as *Ideonella sakaiensis*, which has been shown to degrade polyethylene terephthalate (PET) (Sevilla et al 2023). In addition to *Bacillus* species, which were also identified in this study, other bacteria with reported LDPE-degrading abilities include *Methylobacterium radiotolerans* (Nademo et al 2023), *Alcanivorax* sp., *Cobetia* sp., *Methylobacterium fujisawaense*, *Halomonas* sp., *Lysinibacillus fusiformis*, *Exiguobacterium* sp. (Khandare et al 2021), *Pseudomonas aeruginosa* (Maroof et al 2021), and *Paenibacillus* sp. (Bardají et al 2019).

The results of this study underscore the potential of *Stenotrophomonas* strain MB5, *Bacillus* strain MB7, and *Photobacterium* strain MB11 for plastic bioremediation applications, particularly in the degradation of LDPE. Additionally, this research enhances our understanding of microbial diversity, particularly indigenous bacteria from Manado Bay, Indonesia, which could contribute to plastic degradation. The potential of these indigenous bacteria as plastic degraders is further supported by their direct isolation from plastic-contaminated environments. Ongoing research in our laboratory focuses on molecular and biochemical analyses to identify the specific enzymes and genes involved in the degradation process of *Stenotrophomonas* strain MB5, *Bacillus* strain MB7 and *Photobacterium* strain MB11.

Conclusions. This study demonstrated that indigenous bacteria isolated from Manado Bay, North Sulawesi - *Stenotrophomonas* strain MB5, *Bacillus* strain MB7, and *Photobacterium* strain MB11 - possess the ability to degrade LDPE plastics. The biodegradation potential of these isolates, evidenced by the formation of clear zones and a reduction in LDPE mass after incubation, highlights their promising role as natural plastic-degrading agents. These findings suggest that indigenous marine bacteria could be effectively utilized in future bioremediation strategies to mitigate plastic pollution in marine ecosystems.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

- Andrady A. L., 2017 The plastic in microplastics: a review. *Marine Pollution Bulletin* 119(1): 12-22.
- Bagheri A. R., Laforsch C., Greiner A., Agarwal S., 2017 Fate of so-called biodegradable polymers in seawater and freshwater. *Global Challenges* 1(4):1700048.
- Bardají D. K. R., Furlan J. P. R., Stehling E. G., 2019 Isolation of a polyethylene degrading *Paenibacillus* sp. from a landfill in Brazil. *Archives of Microbiology* 201(5): 699-704.
- Benson N. U., Bassey D. E., Palanisami T., 2021 COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint. *Heliyon* 7(2):e06343.
- Din S. U., Kalsoom, Satti S. M., Uddin S., Mankar S. V., Ceylan E., Hasan F., Khan S., Badshah M., Beldüz A. O., Çanakçı S., Zhang B., Linares-Pastén J. A., Shah A. A., 2023 The purification and characterization of a cutinase-like enzyme with activity on polyethylene terephthalate (PET) from a newly isolated bacterium *Stenotrophomonas maltophilia* PRS8 at a mesophilic temperature. *Applied Sciences* 13(6):3686.
- Fibriarti B. L., Feliatra, Amin B., Darwis, 2021 Biodegradation of LDPE plastic by local strain of *Bacillus* sp. isolated from dump soil of Pekanbaru, Indonesia. *Biodiversitas* 22(12): 5484-5490.

- Ginting E. L., Kemer K., Wullur S., Uria A. R., 2019 Identification of proteolytic thermophiles from Moinit Coastal Hot-Spring, North Sulawesi, Indonesia. *Geomicrobiology Journal* 37(1):50-58.
- Ginting E. L., Poluan G. G., Wantania L. L., Moko E. M., Warouw V., Siby M. S., Wullur S., 2021 Screening and identification of sponge-associated chitinolytic bacteria by forming chitosan from Manado Bay, Indonesia. *Pakistan Journal of Biological Sciences* 24(2):227-234.
- Huang Q. S., Yan Z. F., Chen X. Q., Du Y. Y., Li J., Liu Z. Z., Xia W., Chen S., Wu J., 2022 Accelerated biodegradation of polyethylene terephthalate by *Thermobifida fusca* cutinase mediated by *Stenotrophomonas pavanii*. *Science of the Total Environment* 808:152107.
- Jambeck J. R., Geyer R., Wilcox C., Siegler T. R., Perryman M., Andrady A., Narayan R., Law K. L., 2015 Plastic waste inputs from land into the ocean. *Science* 347(6223):768-771.
- Jebashalomi V., Charles P. E., Rajaram R., 2024 Microbial degradation of low-density polyethylene (LDPE) and polystyrene using *Bacillus cereus* (OR268710) isolated from plastic-polluted tropical coastal environment. *Science of the Total Environment* 924:171580.
- Ji S. H., Yoo S., Park S., Lee M. J., 2024 Biodegradation of low-density polyethylene by plasma-activated *Bacillus* strain. *Chemosphere* 349:140763.
- Jiang P., Zhao S., Zhu L., Li D., 2018 Microplastic-associated bacterial assemblages in the intertidal zone of the Yangtze Estuary. *Science of the Total Environment* 624:48-54.
- Khandare S. D., Chaudhary D. R., Jha B., 2021 Marine bacterial biodegradation of low-density polyethylene (LDPE) plastic. *Biodegradation* 32(2):127-143.
- Kibria M. G., Masuk N. I., Safayet R., Nguyen H. Q., Mourshed M., 2023 Plastic waste: challenges and opportunities to mitigate pollution and effective management. *International Journal of Environmental Research* 17(1):20.
- Lalrinfela P., Vanlalsangi R., Lalrinzuali K., Babu P. J., 2024 Microplastics: their effects on the environment, human health, and plant ecosystems. *Environmental Pollution and Management* 1:248-259.
- Lascu I., Mereuță I., Chiciudean I., Hansen H., Avramescu S. M., Tănase A. M., Stoica I., 2021 Complete genome sequence of *Photobacterium ganghwense* C2.2: a new polyhydroxyalkanoate production candidate. *Microbiology Open* 10(2):e1182.
- Lebreton L. C. M., Van der Zwet J., Damstreeg J. W., Slat B., Andrady A., Reisser J., 2017 River plastic emissions to the world's oceans. *Nature Communications* 8:15611.
- Lou Y., Ekaterina P., Yang S. S., Lu B., Liu B., Ren N., Corvini P. F. X., Xing D., 2020 Biodegradation of polyethylene and polystyrene by greater wax moth larvae (*Galleria mellonella* L.) and the effect of co-diet supplementation on the core gut microbiome. *Environmental Science and Technology* 54(5):2821-2831.
- Mareddy A. R., 2017 *Environmental impact assessment: theory and practice*. Butterworth-Heinemann, Elsevier, 632 pp.
- Mukanto, Rahayu Y. S., Lisdiana L., Pranamuda H., 2015 Isolation of oxo-degradable polyethylene degrading-bacteria of Benowo Landfill Soil Surabaya. *Microbiology Indonesia* 9(1):9-16.
- Maroof L., Khan I., Yoo H. S., Kim S., Park H. T., Ahmad B., Azam S., 2021 Identification and characterization of low-density polyethylene-degrading bacteria isolated from soils of waste disposal sites. *Environmental Engineering Research* 26(3):200167.
- Mukherjee S., Bassler B. L., 2019 Bacterial quorum sensing in complex and dynamically changing environments. *Nature Reviews Microbiology* 17:371-382.
- Nademo Z. M., Shibeshi N. T., Gameda M. T., 2023 Isolation and screening of low-density polyethylene (LDPE) bags degrading bacteria from Addis Ababa municipal solid waste disposal site Koshe. *Annals of Microbiology* 73:6.
- Rachmawati A. C., Mahardika A., Djohan, Susanto A. B., Andriana B. B., 2021 Exploration of plastic-degrading bacteria from Marina Beach, Semarang, Central Java. *Indonesian Journal of Marine Sciences* 26(4):247-253.

- Roager L., Sonnenschein E. C., 2019 Bacterial candidates for colonization and degradation of marine plastic debris. *Environmental Science and Technology* 53(20):11636-11643.
- Schlundt C., Welch J. L. M., Knochel A. M., Zettler E. R., Amaral-Zettler L. A., 2020 Spatial structure in the "plastisphere": molecular resources for imaging microscopic communities on plastic marine debris. *Molecular Ecology Resources* 20(3):620-634.
- Sevilla M. E., Garcia M. D., Perez-Castillo Y., Armijos-Jaramillo V., Casado S., Vizuite K., Debut A., Cerda-Mejía L., 2023 Degradation of PET bottles by an engineered *Ideonella sakaiensis* PETase. *Polymers* 15(7):1779.
- Sharma S., Mohler J., Dahajan S. D., Schwartz S. A., Bruggemann L., Aalinkeel R., 2023 Microbial biofilm: a review on formation, infection, antibiotic resistance, control measures, and innovative treatment. *Microorganisms* 11(6):1614.
- Shemesh R., Novik A., Chen Y., 2010 Follow the leader: preference for specific amino acids directly following the initial methionine in proteins of different organisms. *Genomics, Proteomics and Bioinformatics* 8(3):180-189.
- Tatar A., 2018 Microbial enhanced oil recovery: microbiology and fundamentals. In: *Fundamentals of enhanced oil and gas recovery from conventional and unconventional reservoirs*. Bahadori A. (ed), Gulf Professional Publishing, pp. 291-508.
- Wani S. J., Shaikh S. S., Tabassum B., Thakur R., Gulati A., Sayyed R. Z., 2016 *Stenotrophomonas* sp. RZS 7, a novel PHB degrader isolated from plastic contaminated soil in Shahada, Maharashtra, Western India. *3 Biotech* 6(2):179.
- Wright S. L., Kelly F. J., 2017 Plastic and human health: a micro issue? *Environmental Science and Technology* 51(12):6634-6647.
- Wullur S., Napitupulu H., Wantania L. L., Ginting E. L., Warouw V., Tilaar S., Tallei T. E., Rumengan I. F. M., 2020 Molecular identification of bacteria isolated from culture medium of rotifer fed on fishery waste diet. *Biodiversitas* 21(6):2735-2740.

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