International Journal of Advanced Science and Technology

Country Australia - JI!I. SIR Ranking of Australia

Subject Area and Category
Computer Science
Computer Science (miscellaneous)
Energy
Energy (miscellaneous)
Engineering
Engineering (miscellaneous)

Publisher Science and Engineering Research Support Society

Publication type Journals

ISSN 22076360,20054238

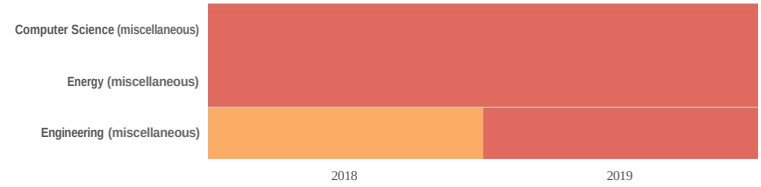
Coverage 2016-2020

Scope Information not localized

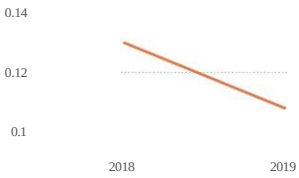
3

H Index

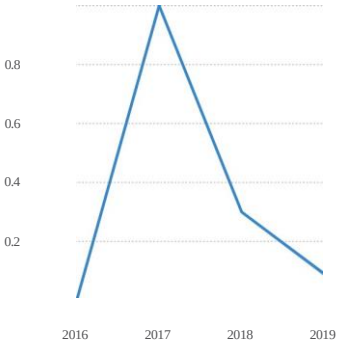
Quartiles



eSJR

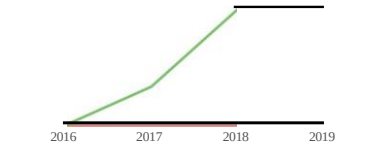


Citations per document

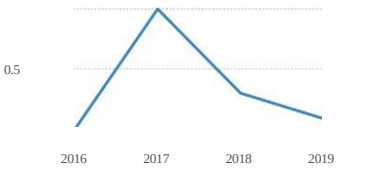


Cites/ Doc. (4 years)
Cites / Doc. (3 years)
Cites/ Doc. (2 years)

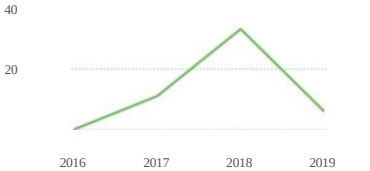
Total Cites Self-Cites



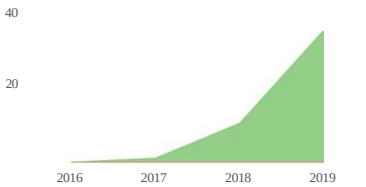
External Cites per Doc Cites per Doc



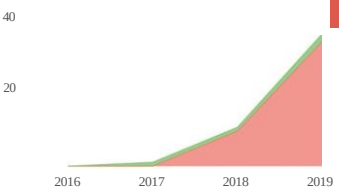
%International Collaboration



Citable documents Non-citable documents



Cited documents Uncited documents



International Journal of Advanced Science and-

Computer Science (miscellaneous)

quartile

SJA2019

0.11

powered by scimagoJr .com

+- Show this widget in your own website

Just copy the code below and paste within your html code:

<a href="https://www.scima

International Journal of Advanced Science and Technology

Scopus coverage years: from 2016 to Present

Publisher: NADIA

ISSN: 2005-4238 E-ISSN: 2207-6360

Subject area: (Energy: General Energy) (Computer Science: General Computer Science) (Engineering: General Engineering)

View all documents>

iiFHh::+iEH El Save to source list Journal Homepage

CiteScore 2019
0.0 ©
Add CiteScore to your site

SJR 2019
0.108 ©

SNIP 2019
0.085 ©

CiteScore CiteScore rank&.trend Scopus content coverage

Improved CiteScore methodology x

CiteScore 2019 counts the citations received in 2016-2019 to articles, reviews, conference papers, book chapters and data papers published in 2016-2019, and divides this by the number of publications published in 2016-2019. Learn more>

CiteScore 2019 II

0.0 = 35 Citations 2016 - 2019
1,437 Documents 2016 - 2019

Calculated on 06 May, 2020

CiteScoreTracker 2020 ©

0.1 = 638 Citations to date
4,401 Documents to date

Last updated on 09 August, 2020 • Updated monthly

CiteScore rank 2019 ©

Category	Rank	Percentile
Energy L General Energy	#61/63	3rd
Computer Science L General Computer **Science**	#217/221	2nd

View CiteScore methodology> CiteScore FAQ >

International Journal of Advanced Science and Technology

General Information of IJAST

ISSN: 2005-4238 (Print)

ISSN: 2207-6360 (Online)

Publisher: Science and Engineering Research Support Society

Contact Information

SERSC Australia

Management Office: PO Box 5014, Sandy Bay TAS 7005, Australia

Email: ijast@sersc.org

Publication and Update

Last day of Every Month

Journal Paper Publication Policy

- The publication will not be an Open Access repository (Effective January 2017).
- A maximum of thirty-nine (39) papers will be included in every journal issue (effective April 2013).
- Multiple submission of the same paper on different journal submission will all be discarded (effective January 2017).
- Paper title, author and corresponding author(s) names should be the same to the submitted paper and on the submission system (effective January 2017).
- Each paper should only have one (1) corresponding author and cannot be changed (effective April 2013).
- If plagiarism problem was found, all authors including the corresponded authors cannot submit paper(s) to our journal for three years.
  The paper will be removed even though it was already published, and this will be noticed on the home page (effective April 2013).
- If double submission was found, all authors including the corresponded authors cannot submit paper(s) to our journal for three years.
  The paper will be removed even though it was published, and this will be noticed on the home page (effective April 2013).
- Only paper(s) containing simulation, implementation, case study or other evidence of research advancement will be published.
  Ideal paper can be published after the editorial board grants permission after reviewing the paper (effective April 2013).
- Papers from one country cannot exceed 60% in every journal issue; it will be based by the first authors' nationality (effective July 2014).
- Only one (1) paper from same author can be included in each issue regardless of role and order (effective July 2014).
- SERSC DOES NOT ALLOW ANY AGENTS FROM CHINA to act on our behalf in collecting papers for our journals. SERSC have standard procedures in publication of submitted papers.

Journal Aims

- IJAST aims to facilitate and support research related to control and automation technology and its applications.
- Our Journal provides a chance for academic and industry professionals to discuss recent progress in the area of control and automation.
- To bridge the gap of users who do not have access to major databases where one should pay for every downloaded article; this online publication platform is open to all readers as part of our commitment to global scientific society.

Abstracted/Indexed In

- EBSCO
- ProQuest
- ULRICH
- J-Gate
- OAJI

Current Issue

Vol. 29 No. 12s (2020)

Articles

Vol. 29 No. 06 (2020): Vol. 29 No. 06 (2020)

Articles

International Journal of Advanced Science and Technology
Vol. 29, No. 6, (2020), pp. 3698 - 3707

Potential of Linear Low-Density Polyethlene (LLDPE) Plastic Degradation by Mixed-Cultured Bacteria in Controlled Environment

Melati Ferianita Fachrul*, Astri Rinanti, Tazkiaturrizki and Elsa Dwicania

Department of Environmental Engineering, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Jakarta, Indonesia
melati@trisakti.ac.id

Abstract

This preliminary study was aimed to determine the ability of mixed-cultured Pseudomonas aeruginosa and Brevibacterium sp. in degrading Linear Low-Density Polyethylene (LLDPE). This study was started by preparing the plastics into 1x1 cm^2 cut mechanically. The plastics were placed in a petri dish containing Nutrient Broth (NB) media and mixed-cultured bacteria. The variations of bacterial composition (%) were 10, 50, and 75; variations of temperature (^oC) were 25, 30, 35; variations of acidity (pH) were 5, 7, 9; and variations of contact time (Td; days) were 10, 30, 60, and 90. LLDPE plastic degradation was analyzed using gravimetry, Fourier Transform Infra-red (FTIR) and Scanning Electron Microscope (SEM). Both bacteria were resistance or non-sensitive to LLDPE substance as xenobiotic substrate. According to gravimetry and FTIR analysis, the highest removal was at 30^{o}C, pH 7, with bacterial composition of 75% (v/v) incubated for 30 days. Gravimetry analysis result showed a loss of LLDPE plastic weight from 0.1548 gram to 0.1464 gram, or 70.67%. The result was reconfirmed using SEM analysis, which showed morphological changes of LLDPE plastic sample surface. Although the degradation occurred very slow, mixed-cultured bacteria has a potential for capacity increase in degrading LLDPE in further studies, including the addition of co-substrate in continuous culture.

Keywords: *brevibacterium sp., pseudomonas aeruginosa, linear low-density polyethylene, xenobiotic, FTIR*

1. Introduction

Plastic is deliberately produced to be impenetrable by oxygen (O_2), thus requires longer time to decompose or degrade naturally by microorganisms involved in decomposition. Other than, plastic has several advantages, i.e. anti-rust, flexible, strong, light, not easily broken, easy to color, resistance to various chemical substances, insulation against electricity, and low density. One common type of plastic is ethylene monomer long chain polyethylene polymers (C_2H_4) [1], [2]. Other than light, transparent, and economical, polyethylene (PE) plastic has resistance property, thus difficult to degrade naturally, which lead to accumulation in the environment [3].

Plastics buried in soil will hinder or inhibit the process of water absorption by plants, thus interrupting photosynthesis process. The life of animals in the soil is disrupted and even causes death due to entrapment in plastic waste or due to ingestion of plastic waste. These animals are vital components in material and energy flow in the soil, leading to loss of nutrients in agricultural lands [3]. Plastic waste in water can also jeopardize the marine ecosystem, especially affecting food chain in the waters.

Polyethylene can be degraded by UV light at 280-300 nm wavelength for 10 days to form hydroperoxide and disconnect polyethylene long chain to form shorter fragments known as monomers [4]. However, degradation process using UV light has negative

effect, i.e. the greenhouse effect. Burning plastic waste will also cause negative effect, in which air pollution caused by gasses resulting from burning plastic, including Carbon Dioxide (CO_2) and Carbon Monoxide (CO). Therefore, a solution is needed to process plastic waste without endangering environment.

Other alternative that has been developed in the last 10 years is biotechnological plastic degradation by utilizing microorganisms. Biodegradation process occurs because complex substances are used by microorganisms as nutrient source or energy source for their growth by utilizing enzymes to breakdown complex substances into more simple substances [5], [6]. According to [7], *Microbacterium paraoxydans* and *Pseudomonas aeruginosa* was known to have the ability to breakdown polymers efficiently with removal percentage of 61.0%, while *P. aeruginosa* in growth media can degrade LDPE plastic with 50.5% efficiency in 2 months. Polymers were broken down into smaller polymers by *M. paraoxydans* and *P. aerugi*nosa used as carbon source. This degradation process is started by the formation of a biofilm in the polymer surface. The biofilm contains microorganism cells which creates a layer in hydrated matrix from polysaccharides and proteins on the surface of the plastic [8]. Based on [5], there was a decrease of plastic weight incubated in media for 120 days and increase of biofilm cells for the first 40 days of incubation.

Each microorganism has different characteristics, thus the degradation process of one microorganism would be different or varies from other microorganisms. Based on this description, this study is required to test the ability of mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp*. As biodegradator in the process of LLDPE plastic processing in controlled laboratory scale.

2. Methodology

2.1. Bacteria Cultivation and Preparation of Plastic Samples

The mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* was obtained from the collection of Microbiology Laboratory of Environmental Engineering, Universitas Trisakti. Cultivation of mixed-cultured bacteria was conducted in batch culture in Erlenmeyer flask aerobically, which contained growth media, nutrient broth (NB). Bacterial growth was observed every day. After reaching exponential phase, the mixed culture bacteria were ready to be tested. LLDPE samples were cut mechanically to form 1x1 cm^2, the smaller the plastic, the higher the surface area, thus higher chance for effective contact with degradation bacteria.

2.2. Sensitivity Test

Before the main study, sensitivity test was conducted to determine the vulnerability of *Pseudomonas aeruginosa* and *Brevibacterium sp.* on LLDPE sample as xenobiotic substance which can inhibit growth or kill bacteria in certain concentration [9]. LLDPE sample was placed in the center of a petri dish containing mixed-cultured bacteria and growth media. Inhibition zone formation surrounding plastic sample showed inhibition of culture growth, thus cannot be used as biodegradator and vice versa.

2.3. Research Design

The dependent variable in this study was linear low-density polyethylene (LLDPE) plastic samples, while the independent variables were composition of mixed-cultured bacteria (%; v/v), temperature (^oC), acidity (pH), and contact time (Td; days). Variations in the composition of mixed-cultured bacteria were 10%, 50%, and 75% of total solution volume. Optimum temperature and pH were

determined by variations of tropical temperature (^{o}C) which were 25, 30, and 35 and with pH variations of 5, 7, and 9 which represented acid, neutral, and alkaline. This study was conducted by placing 1% (w/v) LLDPE sample in testing reactor containing growth media from 10%, 50%, 75% (v/v) mixed-cultured bacteria. This study was conducted for 90 days with 3 times repetition performed on contact time (Td; days) 10, 30, 60, and 90. Afterwards, gravimetry, Fourier Transform Infra-red (FTIR) and Scanning Electron Microscope (SEM) analyses were conducted.

2.4. Gravimetric Analysis

Gravimetry was used to determine the percentage of LLDPE plastic sample weight loss. Gravimetry is a quantitative chemical analysis based on the principle of plastic sample measurement before and after degradation. Therefore, the percentage of degraded plastic weight loss can be determined. According to [9], the percentage of degraded plastic weight loss can be determined by the following formula:

$$\%\, weight\ loss = \frac{W(a) - W(b)}{W(a)} x\ 100\% \quad (1)$$

W(a): plastic weight before degradation
W(b): plastic weight after degradation

2.5. Fourier Transform Infra-red (FTIR) Analysis

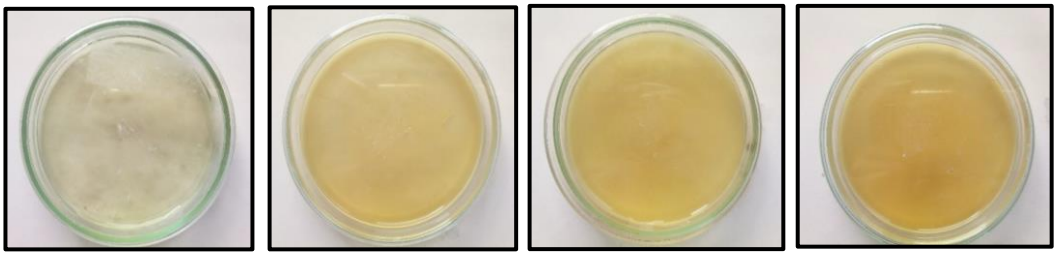
Plastic content analysis using Fourier Transform Infra-red (FTIR) based on infra-red spectrum was conducted to determine changes in functional groups of LLDPE sample before and after contact to mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp*. LLDPE Biodegradation can be confirmed within 2500-3000 cm-1 wavenumber, which is the typical peak of PE substance [7].

2.6. Scanning Electron Microscope (SEM) Analysis

This analysis was conducted to determine morphological structure and shape of LLDPE sample surface before and after incubation with mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp*. The morphology of LLDPE sample which completed biodegradation process by bacterial activity was observed with SEM using 10-3,000,000 magnification, 4-0.4 mm depth of field and 1-10 nm resolution.

3. Results and Discussion

The growth of mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp*. in liquid media Nutrient Broth (NB) containing LLDPE sample was shown by changes in color. Color changes occurred gradually from transparent to cloudy yellow observed on Day-30, Day-60, and Day 90 showed increased bacterial concentration of *Pseudomonas aeruginosa* and *Brevibacterium sp.* in liquid media Nutrient Broth (NB) (Figure 1).



(a) **(b)** **(c)** **(d)**

Figure 1. The growth of *Pseudomonas aeruginosa* and *Brevibacterium sp.* surrounding LLDPE sample (a) 0 day, (b) 30 days, (c) 60 days, and (d) 90 days

These color changes revealed that the growth activity of mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp*. was not disturbed by LLDPE plastic sample with xenobiotic property. These bacteria were suspected to grow by using carbon substance (C) as a nutrient source in growth media contained in LLDPE sample.

The result of sensitivity test showed that there was no inhibition zone surrounding LLDPE sample, thus mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* can be considered resistant or non-sensitive to toxic xenobiotic substance (Figure 2). Therefore, these mixed-cultured bacteria were suspected to have the ability to degrade or decompose LLDPE plastic.

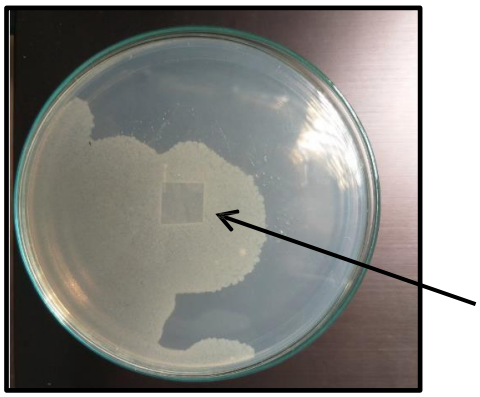


Figure 2. Mixed-cultured bacteria can grow well on Day-48 shown by no inhibition zone surrounding LLDPE sample

3.1. Reduced Weight of LLDPE Sample

Removal efficiency according to reduced weight of LLDPE sample on variations of temperature and pH, and addition of 10%, 50%, and 75% (v/v) mixed-cultured bacteria to a media containing 1% (w/v) LLDPE sample for 30 days of study can be seen in Figure 3. Based on the figure, the addition of 75% (v/v) mixed-cultured bacteria provided removal efficiency of 5.47% at 30^{o}C and pH 7 for 30 days of incubation, proven by reduced sample size from 0.1548 gram to 0.1464 gram. This result showed that LLDPE polymer degradation occurs very slowly. Furthermore, more biodegradator causes more reduction of LLDPE sample weight. Biodegradation process occurs from the breakdown of polymer into monomers or smaller components, then these monomers are mineralized through the process of organic substance change to inorganic. Polymers that are too large to pass through cell membrane should be polymerized to smaller monomers before absorbed and degraded in microbial cells [10], [11]. The study was continued until Day-90, where it is expected to give higher removal result (degradation).

Figure 4 depicted removal efficiency (%; v/v) according to reduced LLDPE sample weight for 90 days at 30^{o}C and pH 7 with the addition of 75% (v/v) mixed-cultured bacteria. Removal efficiency kept increasing to 5.47% on Day-30, however reduced after Day-30 to the end of the study on Day-90. Increased removal efficiency occurred because mixed-culture bacteria performed optimum growth activity or in exponential phase. According to Maier (2008), this phase is marked by fast bacterial growth in current condition. This proved that although degradation

process had occurred by mixed-cultured bacteria as biodegradator by utilizing carbon substance in LLDPE as a nutrient source, the process occurs very slowly. These results were supported by the result of a study [5] which stated that there was a reduced plastic sample weight of 20% incubated in media for 120 days by *Pseudomonas aeruginosa*. Plastic biodegradation process which utilizes microorganism activity is a very slow process, and certain microorganisms are unable to decompose plastic because they do not have enzyme suitable to the substrate or plastic which will be degraded [1], [12].

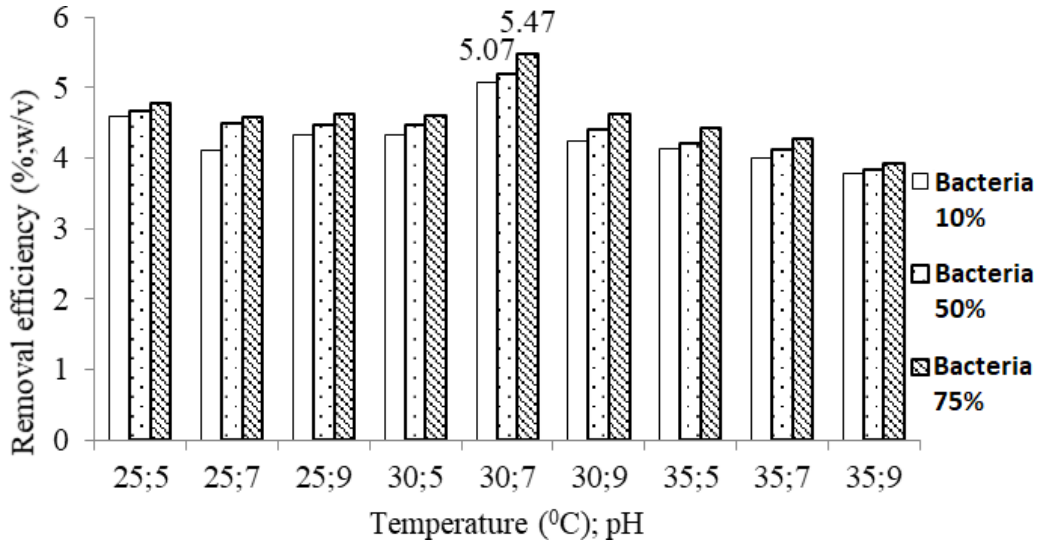


Figure 3. Removal Efficiency (%, w/v) on Day-30 on Variations of Temperature and pH with Addition of 10%, 50%, and 75% (v/v) Mixed-Culture Bacteria

Low plastic removal for 30 days at 30^{o}C and pH 7 may also be due to the enzyme contained by mixed-cultured bacteria did not act properly. Enzyme work is highly influenced by environmental condition, which include temperature, pH, oxygen availability, nutrient availability with correct carbon to nitrogen to phosphor ratio (C:N:P). Other than these factors, in order to improve enzyme activity in accelerating LLDPE degradation process, enzyme requires chemical substances in the form of molecules or ions which can improve the biological activity of enzyme, known as co-substrate.

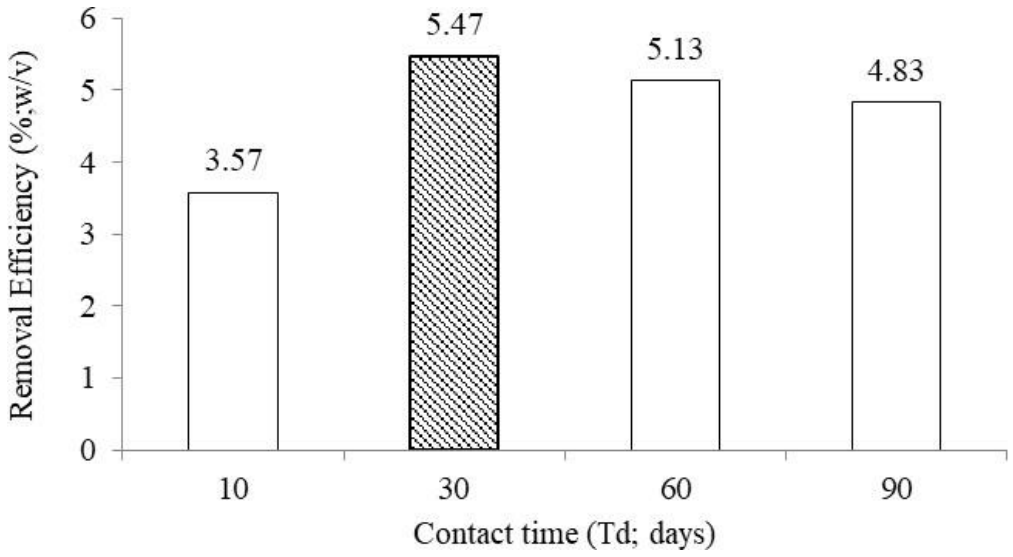


Figure 4. Removal Efficiency (%; w/v) until Day-90

The most commonly used co-substrate is starch. Starch is often used as plastic making material with biodegradable property because starch has several advantages, including abundant amount in the environment, can hold oxygen well, and affordable [11]. The mixture of hydrocarbon polymer and starch is often used to produce high quality plastic film and layers. More starch used in plastic making, the higher the biodegradability. According to [1], [14], biodegradation of a polymer is also affected by physical and chemical characteristics, including the availability of functional group which increases hydrophobic (degradation process in hydrophilic is faster compared to hydrophobic), molecular weight, molecular composition, physical shape and properties of polymer, and polymer density.

3.2. Fourier Transform Infra-red (FTIR) Analysis

Weight loss according to the composition of mixed-cultured bacteria in gravimetry analysis was confirmed by FTIR analysis. The intensity of functional group of LLDPE sample that did not given mixed-cultured bacteria addition on t0 or as baseline intensity was 0.098 on 2916.37 cm-1 wavenumber. Observation to Day-90 showed that the intensity stayed at 0.098 on 2916.37 cm-1 wavenumber. This showed that there were no changes in functional group intensity in LLDPE plastic without the existence of mixed-cultured bacteria.

The results of FTIR analysis on variations of temperature, pH and addition of mixed-cultured bacteria for 30 days of incubation showed changes of reduced intensity of LLDPE sample functional group on every treatment (Figure 5).

The highest intensity reduction occurred in 75% (v/v) mixed-cultured bacteria addition, at 30^{o}C and pH 7. The intensity changed from 0.098 to 0.028, which obtained 70.67% efficiency of functional group intensity. This proved that a condition 30^{o}C and pH 7 was suitable for the growth of mixed-cultured bacteria, which lead to a more optimal plastic degradation. This study also proved that these mixed-cultured bacteria were included in mesophilic group, which can grow well within 20-45^{o}C and pH range of 5.5-8.0. Greater number of bacteria used as biodegradator also affected degradation process. More bacteria mean more enzyme produced to catalyze more sample, which lead to better degradation. The study was continued until Day-90 with the addition of 75% (v/v) mixed-cultured bacteria at

30°C and pH 7, with the expectation of higher efficiency of functional group intensity.

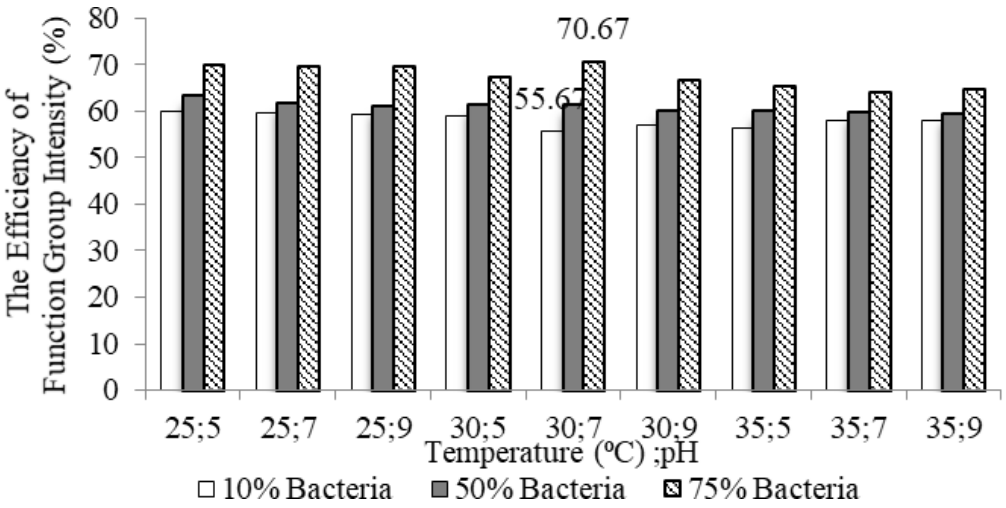


Figure 5. The Efficiency of Functional Group Intensity (%) on Various Treatments for 30 days

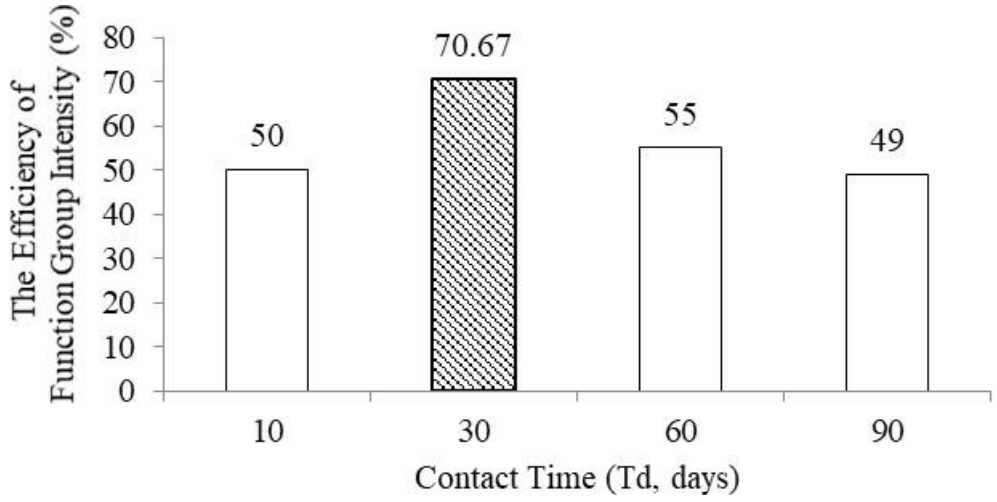


Figure 6. Efficiency of Functional Group Intensity (%) until Day-90

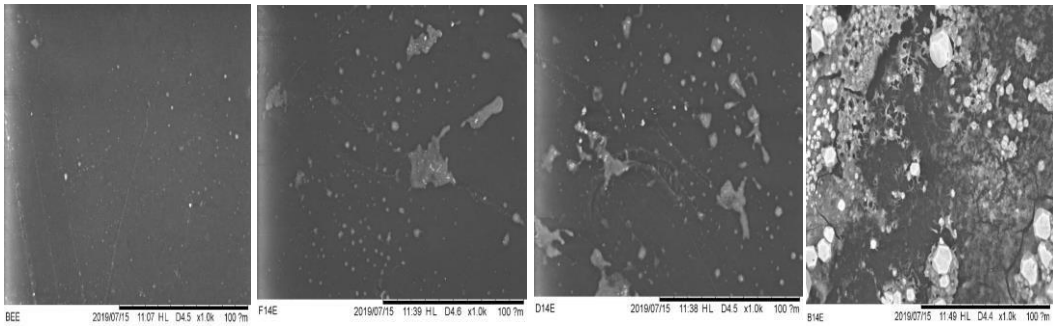
Contrary to expectation, after 30 days of incubation period, the efficiency of functional group removal did not improve until Day-90 (Figure 6). Seventy-five percent (v/v) mixed-cultured bacteria as biodegradator was apparently insufficient to improve degradation efficiency. Although bacteria can still be found on Day-90, the density was reduced 70%. The enzyme produced by mixed-cultured bacteria was seemingly not suitable with LLDPE sample as substrate. The role of enzyme in this process was as a biocatalyst which acted in accelerating chemical reactions without reacting. However, enzyme works specifically, like lock and key, whereas the catalyst substrate should be suitable with the type of enzyme. According to [12], [14], the enzyme produced by bacteria varies in several species of bacteria. *Brevibacillus spp.* is known to degrade polyethylene because it produces protease

enzyme, while *Pseudomonas spp*. produced hydrolase, esterase, and lipase. This was supported by [13], [8] which explained that plastic biodegradation by microorganisms occurred due to hydrolysis or oxidation process by the enzyme owned by microorganism to breakdown polymer substance, aerobically or anaerobically.

Low efficiency of LLDPE removal can also be caused by inappropriate culture batch condition, which lead to ineffective contact between mixed-cultured bacteria and sample. Furthermore, the availability of nutrient in growth media kept decreasing until Day-90. One of the factors that affected biodegradation process is a component of a substrate or the size of a substrate. Biodegradation process will occur faster in a simpler substrate making molecules or smaller substrate size. Otherwise, a more complex molecules and larger substrate requires longer time to decompose or degrade [6], [14]. Further studies are needed with the addition of co-substrate in a continuous culture to ensure nutrient availability until the end of observation period.

3.3. Scanning Electron Microscope (SEM) Analysis

LLDPE sample along with 75% (v/v) mixed-cultured bacteria incubated for 30 days at 30^{o}C and pH 7 was reported to have efficiency of 5.47% and 70.67% according to gravimetry and FTIR analysis, respectively. Afterwards, SEM analysis was conducted to confirm whether there were morphological changes in LLDPE plastic sample surface.



a) Plastic + Nutrient Broth (NB) media

b) Plastic + NB media + 10% (v/v) mixed-cultured bacteria

c) Plastic + NB media + 50% (v/v) mixed-cultured bacteria

d) Plastic + NB media + 75% (v/v) mixed-cultured bacteria

Figure 7. Morphological Changes of LLDPE Sample Surface at 30^{o}C, pH 7

Figure 7 visually depicted morphological changes on LLDPE plastic surface, from smooth, non-porous to damage with fine pores on the surface. Incomplete biodegradation process seemed to occur by mixed-cultured bacteria which were suspected to utilize the plastic as carbon or nutrient source for their growth. The loss of 5.47% plastic weight during 30 days of incubation showed that decomposition or degradation of LLDPE plastic occurred very slowly because morphological changes only occurred on the plastic surface. Physically, the LLDPE sample had not completely broken down on Day-90. Slow biodegradation process may be due to linear low-density polyethylene (LLDPE) is a synthetic polymer consisted of molecules with linear polyethylene with monomer ethylene long chain (C_2H_4) with 0.90-0.94 g/cm^3 density [5], [7]. Other than that, plastic is a substance or substrate foreign to biological system, thus produced resistance due to unsuitability of substrate with available enzyme [9], [10], [14] Biofilm layer consists of microorganism, 80-95% water, inorganic particles, and 85-98% extracellular

polymer substance that came from organic materials. The formation of microorganism cells on polymer surface as biofilm is known as biofouling [8], [12].

4. Conclusion

Mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* in controlled environment on all variations of temperature and pH can degrade LLDPE sample, although the process was very slow. The highest degradation based on removal efficiency from lost weight and efficiency of functional group intensity reduction were each 5.47% and 70.67% and occurred when 75% of mixed-cultured bacteria was added as degradator, and environmental condition was set to 30 ^{o}C and pH 7. Degradation did not increase until Day-90. This may be due to reduced nutrients and inappropriate culture batch condition. Therefore, further studies should be conducted with the addition of co-substrate in continuous culture to ensure nutrient availability until the end of observation period.

Acknowledgements

The authors would like to thank Directorate for Research and Community Services as well as Directorate General for Strengthening Research and Development at the Ministry of Research, Technology, and Higher Education Indonesia for funding this study through Prime University Basic Research Grant Program (Penelitian Dasar Unggulan Perguruan Tinggi-PDUPT) 2019/2020.

References

[1] F. Alshehrei, "Biodegradation of Synthetic and Natural Plastic by Microorganisms", Journal of Applied & Environmental Microbiology, vol. 5, no. 1, (**2017)**, pp. 8-19.

[2] S. K. Mohan, T. Srivastava, "Microbial Deterionation and Degradation of Polymeric Materials", J. Biochem., vol. 2, no. 4, **(2010).** pp. 210-215.

[3] R. Usha, T. Sangeetha, M. Palaniswamy, "Screening of Polyethylene Degrading Microorganisms from Garbage Soil", Libyan Agric. Res. Cen. J. Intl., vol. 3, no. 4, **(2011)**, pp. 200-204.

[4] R. O. Asriza, P. Janiar, "Photodegradation of High Density Polyethylene Containing Oxo-Biodegradation Additives" Ind. J. Chem. Res., vol. 4, no. 2, **(2017)**, pp. 402-405.

[5] B. M. Kyaw, R. Champakalakshmi, M. K. Sakharkar, C. S. Lim, K. R. Sakharkar, "Biodegradation of Low Density Polythene (LDPE) by Pseudomonas Species", Indian Journal of Microbiology, vol. 52, no. 3, **(2012)**, pp. 411-419.

[6] T. I. Poznyak, O. I. Chairez, A. S. Poznyak, "Biodegradation", in Ozonation and Biodegradation in Environmental Engineering. Tatyana Poznyak, Jorge Isaac Chairez Oria, Alex Poznyak (Eds.), Amsterdam: Elsevier, (**2019)**, pp. 353-388.

[7] H. Rajandas, S. Parimannan, K. Sathasivam, M. Ravichandran, L. S. Yin, "A Novel FTIR-ATR Spetroscopy Based Tecnique for the Estimation of Low-Density Polyethylene Biodegradation", Polymer Testing, vol. 3, no. 8, **(2012)**, pp. 1094-1099.

[8] R.M. Donlan, "Biofilms: Microbial Life on Surfaces", Emerging Infectious Diseases, vol. 8, no. 9, **(2002),** pp. 881-890.

[9] K. Eunike, A. Rinanti, R. Ratnaningsih, "Potentialof Indigenous Bacteria to Remove Cyanide with Variations of Contact Time and Temperature", MATEC Web of Conferences vol. 197, **(2018)**, pp. 1-4.

[10] R. M. Maier, "Bacterial Growth", in Environmental Microbiological. Pepper, I. L., Gerba, C. P., & Gentry, T. J. (Eds.), Massachusetts: Academic Press, (**2015**), pp. 37-56.

[11] V. Yunar, Evaluasi Biodegradabilitas Plastik Berbahan Dasar Campuran Pati dan Polietilen Menggunakan ASTM G21-09: Uji Mikroorganisme dan Uji Lapangan. Skripsi, Universitas Indonesia, Depok, (**2011**).

[12] H. Bhardwaj, R. Gupta, A. Tiwari, "Microbial Population Associated with Plastic Degradation", Scientific Reports, vol. 1, no. 272, **(2012)**, pp. 272-274.

[13] S. Kumar, P. M. Das, L. J. Rebecca, S. Sharmila, "Isolation and identification of LDPE degrading fungi from municipal solid waste", Journal of Chemical and Pharmaceutical Research, vol. 5, no. 3, **(2013)**, pp. 78-81.

[14] J. Godheja, S. K. Shekhar, S. A. Siddiqui, D. R. Modi, "Xenobiotic Compounds Present in Soil and Water: A Review on Remediation Strategies", Journal of Environmental and Analytical Toxicology, vol. 6, no. 5, **(2016)**, pp. 1-18.

Potential of Linear Low-Density Polyethlene (LLDPE) Plastic Degradation by Mixed-Cultured Bacteria in Controlled Environment

by Melati Ferianita Fachrul

Submission date: 09-Jul-2020 10:05AM (UTC+0700)
Submission ID: 1355242992
File name: 3_IJAST_LLDPE_Plastic_Degradation.docx (281.46K)
Word count: 3413
Character count: 19856

International Journal of Advanced Science and Technology
Vol. 29, No. 6, (2020), pp. 3698 - 3707

Potential of Linear Low-Density Polyethlene (LLDPE) Plastic Degradation by Mixed-Cultured Bacteria in Controlled Environment

l!J Melati Ferianita Fachrul*, Astri Rinanti, Tazkiaturrizki and Elsa Dwicania

Department of Environmental Engineering, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Jakarta, Indonesia
• *melati@trisakti.ac.id*

Abstract

This preliminary study was aimed to determine the ability of mixed-cultured Pseudomonas aeruginosa and Brevibacterium sp. in degrading Linear Low-Density Polyethylene (LLDPE). This study was started by preparing the plastics into JxJ cm² cut mechanically. The plastics were placed in a petri dish containing Nutrient Broth (NB) media and mixed-cultured bacteria. The variations of bacterial composition(%) were JO, 50, and 75; variations of temperature ("C) were 25, 30, 35; variations of acidity (pH) were 5, 7, 9; and variatfD of contact time (Td; days) were JO, 30, 60, and 90. LLD PE plastic degradation was analyzed using gravimetry, Fourier Transform Infra-red (FTIR) and Scanning Electron Microscope (SEM). Both bacteria were resistance or non-sensitive to LLDPE substance as xenobiotic substrate. According to gravimetry and FTIR analysis, the highest removal was at 30"C, pH 7, with bac/erial composition of 75% (vlv) incubated for 30 days. Gravimetry analysis result showed a loss of LLDPE plastic weight from 0.1548 gram to 0.1464 gram, or 70.67%. The result was reconfirmed using SEM analysis, which showed morphological changes of LLDPE plastic sample swface. Although the degradation occurred very slow, mixed-cultured bacteria has a potential for capacity increase in degrading LLDPE infurrher srudies, including rhe addition of co-substrace in continuous culture.

Keywords: *brevibacterium sp., pseudomonas aeruginosa, linear low-density polyethylene, xenobiotic, FTIR*

1. Introduction

Plastic is deliberately produced to be impenetrable by oxygen (02), thus requires longer time to decompose or degrade naturally by microorganisms involved in decomposition. Other than, plastic has several advantages, i.e. anti-rust, flexible, strong, Jjght, not easily broken, easy to color, resistance to various chemical substances, insulation against electricity, and low density. One common type of plastic is ethylene monomer long chain polyethylene polymers (C2fu) [I], [2]. Other than Light, transparent, and economical, polyethylene (PE) plastic has resistance property, thus difficult to degrade naturally, which lead to accumulation in the environment [3].

Plastics buried in soil will hinder or inhibit the process of water absorption by plants, thus interrupting photosynthesis **processmhe** life of animals in the soil is disrupted and even causes death due to entrapment in plastic waste or due to ingestion of plastic waste. These animals are vital components in material and energy flow in the soil, learung to loss of nutrients in agricultural lands [3]. Plastic waste in water can also jeopardize the marine ecosystem, especially affecting food chrun in the waters.

Polyethylene can be degraded by UV light at 280-300 nm wavelength for 10 days to form hydroperoxide and disconnect polyethylene long cha.in to form shorter fragments known as monomers [4]. However, degradation process using UV light has negative

ISSN: 2005-4238 IJAST

effect, i.e. the greenhouse effect. Burning plastic waste will also cause negative effect, in which air pollution caused by gasses resulting from burning plastic, including Carbon Dioxide (CO2) and Carbon Monoxide (CO). Therefore, a solution is needed to process plastic waste without endangering environment.

Other alternative that has been developed in the last 10 years is biotechnological plastic degradation by utilizing microorganisms. Biodegradation process occurs because complex substances are used by microorganisms as nutrient source or energy source for their growth by utilizing enzymes to breakdown complex substances into more simple substances [51, [6]. According to [71, *Microbacterium paraoxydans* and *Pseudomonas aeruginosa* was known to have the ability to breakdown polymers efficiently with removal percentage of 61.0%, while *P. aeruginosa* in growth media can degrade LOPE plastic with 50.5% efficiency in 2 months. Polymers were broken down into smaller polymers by *M. paraoxydans* and *P. aeruginosa* used as carbon source. This degradation process is started by the formation of a biofilm in the polymer surface. The biofilm contains microorganism cells which creates a layer in hydrated matrix from polysaccharides and proteins on the surface of the plastic [8]. Based on [51, there was a decrease of plastic weight incubated in media for 120 days and increase of biofilm cells for the first 40 days of incubation.

Each microorganism has different characteristics, thus the degradation process of one **microorganimwould** be different or varies from other microorganisms. Based on this description, this study is required to test the ability of mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* As biodegradator in the process of LLDPE plastic processing in controlled laboratory scale.

2. Methodology

2.1. Bacteria Cultivation and Preparation of Plastic Samples

FIJ**The** mixed-cultured *Pseudomonas aeruginosa* and *Brevibac/erium sp.* was obtained from the collection of Microbiology Laboratory of Environmental Engineering, Universitas Trisakti. Cultivation of mixed-cultured bacteria was conducted in batch culture in Erlenmeyer flask aerobically, which contained growth media, nutrient broth (NB). Bacterial growth was observed every day. After reaching exponential phase, the mixed culture bacteria were ready to be tested. LLDPE samples were cut mechanically to form Ix I cm^2, the smaller the plastic, the higher the surface area, thus higher chance for effective contact with degradation bacteria.

2.2. Sensitivity Test

Before the main study, sensitivity test was conducted to determine the vulnerability of *Pseudomonas aeniginosa* and *Brevibacterium sp.* on LLDPE sample as xenobiotic substance which can inhibit growth or kill bacteria in cettain concentration [9]. LLDPE sample was placed in the center of a petri dish containing mixed-cultured bacteria and growth media. Inhibition zone formation surrounding plastic sample showed inhibition of culture growth, thus cannot be used as biodegradator and vice versa.

2.3. Research Design

The dependent variable in this study was linear low-density polyethylene (LLDPE) plastic samples, while the independent variables were composition of mixed-cultured bacteria (%; v/v), temperature (°C), acidity (pH), and contact time (Td; days). Variations in the composition of mixed-cultured bacteria were IO%, 50%, and 75% of total solution volume. Optimum temperature and pH were

determined by variations of tropical temperature (°C) which were 25, 30, and 35 and with pH variations of 5, 7, and 9 which represented acid, neutral, and alkaline. This study was conducted by placing I% (w/v) LLDPE sample in testing reactor containing growth media from 10%, 50%, 75% (v/v) mixed-cultured bacteria. This study was conducted for 90 days with 3 times **repetitio8rformed** on contact time (Td; days) 10, 30, 60, and 90. Afterwards, gravimetry, Fourier Transform Infra-red **(FflR)** and Scanning Electron Microscope **(SEM)** analyses were conducted.

2.4. Gravimetric Analysis

Gravimetry was used to determine the percentage of LLDPE plastic sample weight loss. Gravimetry is a quantitative chemical analysis based on the principle of plastic sample **meaDment** before and after degradation. Therefore, the percentage of degraded plastic **Bight** loss can be determined. According to [9], the percentage of degraded plastic weight loss can be determined by the following formula:

$$\%\,weight\,loss = \frac{W(a)-W(b)}{W(a)} x\ 100\% \quad \text{(I)}$$

W(a): plastic weight before degradation
W(b): plastic weight after degradation

2.5. Fourier Transform **Infra-rrTIR)** Analysis

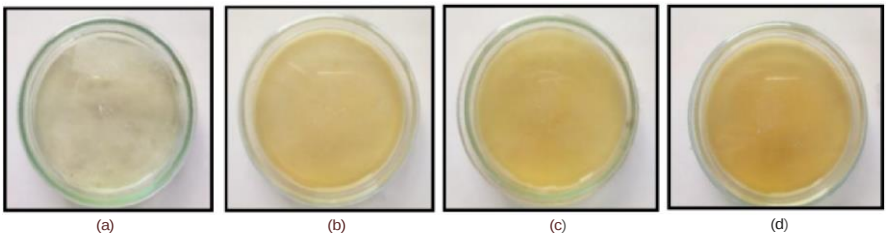
Plastic content analysis using Fourier Transform Infra-red (FflR) based on infra-red spectrum was conducted to determine changes in functional groups of LLDPE sample before and after contact to mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* LLDPE Biodegradation can be confirmed within 2500-3000 cm-I wavenumber, which is the typical peak of PE substance [7].

2.6. Scanning Electron Microscope (SEM) Analysis

This analysis was conducted to determine morphological structure and shape of LLDPE sample surface before and after incubation with mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* The morphology of LLDPE sample which completed biodegradation process by bacterial activity was observed with SEM using 10-3,000,000 magnification, 4-0.4 mm depth of field and 1-10 nm resolution.

3. Results and Discussion

The growth of mixed-cultured *Pseudomonas aeruginosa* and *Brevibacrerium sp.* in liquid media Nutrient Broth (NB) containing LLDPE sample was shown by changes in color. Color changes occurred gradually from transparent to cloudy yellow observed on Day-30, Day-60, and Day 90 showed increased bacterial concentration *Pseudomonas aeruginosa* and *Brevibacterhun sp.* in liquid media Nutrient Broth (NB) (Figure I).



(a) (b) (c) (d)

Figure I. The growth of *P : domonas aeruginosa* and *Brevibacterium sp.* surrounding LLDPE sample (a) 0 day, (b) 30 days, (c) 60 days, and (d) 90 days

These color changes revealed that the growth activity of mixed-cultured *Pseudomonas aeruginosa* and *Brevi/Jacrerium sp.* was not disturbed by LLDPE plastic sample with xenobiotic property. These bacteria were suspected to grow by using carbon substance (C) as a nutrient source in growth media contajned in LLDPE sample.

The result of sensitivity test showed that there was no inhibition zone surrounding LLDPE sample, thus mhed-cultured *Pseudomonas aeruginosa* and *Brevi/Jacterium sp.* can be considered resistant or non-sensitive to toxic xenobiotic substance (Figure 2). Therefore, these mixed-cultured bacteria were suspected to have the ability to degrade or decompose LLDPE plastic.

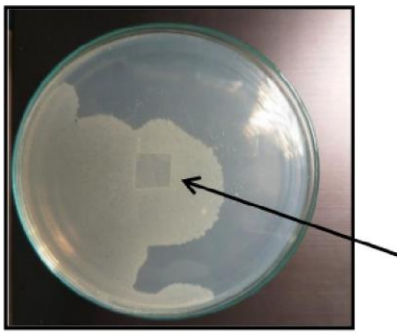


Figure 2. Mixed-cultured bacteria can grow well on Day-48 shown by no inhibition zone surrounding LLDPE sample

3.1. Reduced Weight ofLLDPE Sample

Remova.l efficiency according to reduced weight of LLDPE sample on variations of temperature and pH, and addition of 10%, 50%, and 75% (v/v) mixed-cultured bacteria to a media containing I% (w/v) LLDPE sample for 30 days of study can be seen in Figure 3. Based on the figure, the addition of 75% (v/v) mixed-cultured bacteria provided removal efficiency of 5.47% at 30°C and pH 7 for 30 days of incubation, proven by reduced sample size from 0.1548 gram to 0.1464 gram. This result showed that LLDPE polymer degradation occurs very slowly. Furthermore, more biodegradator causes more reduction of LLDPE sample weight. Biodegradation process occurs from the breakdown of polymer into monomers or smaller components, then these monomers are **miner&led** through the process of organic substance change to inorganic. **l!IYmers** that are too large to pass through cell membrane should be polymerized to smaller monomers before absorbed and degraded in microbial cells [10], [l l]. The study was continued until Day-90, where it is expected to give higher removal result (degradation).

Figure 4 depicted removal efficiency (%; v/v) according to reduced LLDPE sample weight for 90 days at 30°C and pH 7 with the addition of 75% (v/v) mixed-cultured bacteria. RemovaJ efficiency kept increasing to 5.47% on Day-30, however reduced after Day-30 to the end of the study on Day-90. Increased removal efficiency occurred because mixed-culture bacteria performed optimum growth activity or in exponentia.l phase. According to Maier (2008), this phase is marked by fast bacterial growth in current condition. This proved that although degradation

process had occurred by mixed-cultured bacteria as biodegradator by utilizing carbon substance in LLDPE as a nutrient source, the process occurs very slowly. These results were supported by the result of a study [5] which stated that there was a reduced plastic sample weight of 20% incubated in media for 120 days by *Pseudomonas aeruginosa*. Plastic biodegradation process which utilizes microorganism activity is a very slow process, and certain microorganisms are unable to decompose plastic because they do not have enzyme suitable to the substrate or plastic which will be degraded [I], [12].

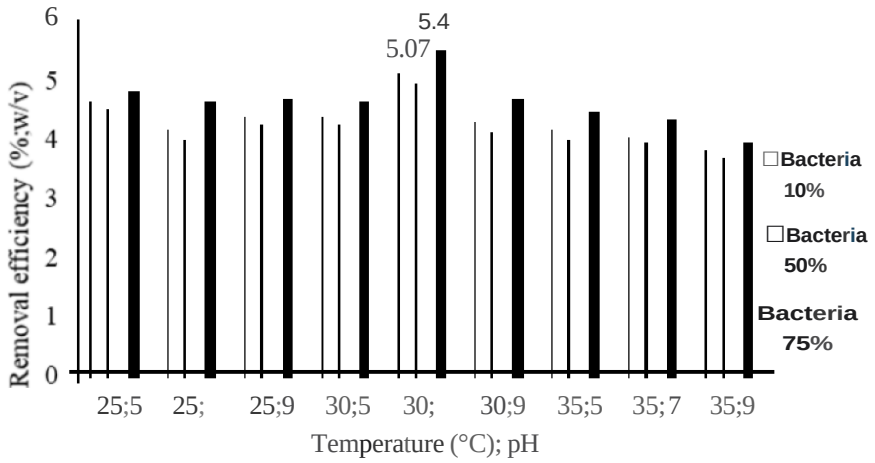


Figure 3. Removal Efficiency(%, w/v) on Day-30 on Variations of Temperature and pH with Addition of IO%, **50%, and 75% (v/v) Mixed-Culture Bacteria**

Low plastic removal for 30 days at 30°C and pH 7 may also be due to the enzyme contained by mixed-cultured bacteria did not act properly. Enzyme work is highly influenced by environmental condition, which include temperature, pH, oxygen availability, nutrient availability with correct carbon to nitrogen to phosphor ratio (C:N:P). Other than these factors, in order to improve enzyme activity in accelerating LLDPE degradation process, enzyme requires chemical substances in the form of molecules or ions which can improve the biological activity of enzyme, known as co-substrate.

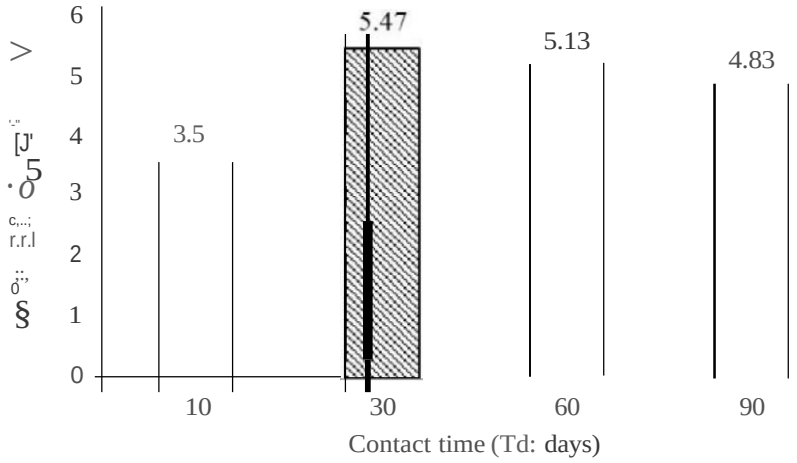


Figure 4. Removal Efficiency(%; w/v) until Day-90

The most commonly used co-substrate is starch. Starch is often used as plastic making material with biodegradable property because starch has several advantages, including abundant amount in the environment, can hold oxygen well, and affordable [II]. The mixture of hydrocarbon polymer and starch is often used to produce high quafay plastic film and layers. More starch used in plastic making, the higher the **biode0dability.** According to [II, [141, biodegradation of a polymer is also affected by physical and chemical characteristics, including the availability of functional group which increases hydrophobic (degradation process in hydrophilic is faster compared to hydrophobic), molecular weight, molecular composition, physicaJ shape and properties of polymer, and polymer density.

fD

3.2. Fourier Transform Infra-red (FTIR) Analysis

Weight loss according to the composition of mixed-cultured bacteria m gravimetry analysis was confirmed by Ff!R analysis. The intensity of functional group of LLDPE sample that did not given mixed-cultured bacteria addition on t0 or as baseline intensity was 0.098 on 2916.37 cm- I wavenumber. Observation to Day-90 showed that the intensity stayed at 0.098 on 2916.37 cm-I wavenumber. This showed that there were no changes in functional group intensity in LLDPE plastic without the existence of mixed-cultured bacteria.

The results of Ff!R analysis on variations of temperature, pH and addition of mixed-cultured bacteria for 30 days of incubation showed changes of reduced intensity of LLDPE sample functional group on every treatment (Figure 5).

The highest intensity reduction occurred in 75% (v/v) mixed-cultured bacteria addition, at 30°C and pH 7. The intensity changed from 0.098 to 0.028, which obtained 70.67% efficiency of functional group intensity. This proved that a condition 30°C and pH 7 was suitable for the growth of mixed-cultured bacteria, which lead to a more optimal plastic degradation. This study also proved that these mixed-cultured bacteria were included in mesophilic group, which can grow well within 20-45°C and pH range of 5.5-8.0. Greater number of bacteria used as biodegradator also affected degradation process. More bacteria mean more enzyme produced to catalyze more sample, which lead to better degradation. The study was continued until Day-90 with the addition of 75% (v/v) mixed-cultured bacteria at

30°C and pH 7, with the expectation of higher efficiency of functiona.l group intensity.

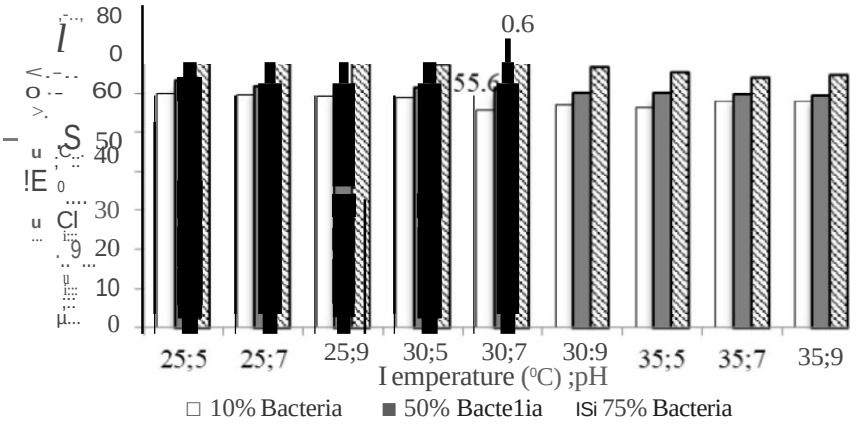


Figure 5. The Efficiency of Functional Group Intensity (%) on Various Treatments for 30 days

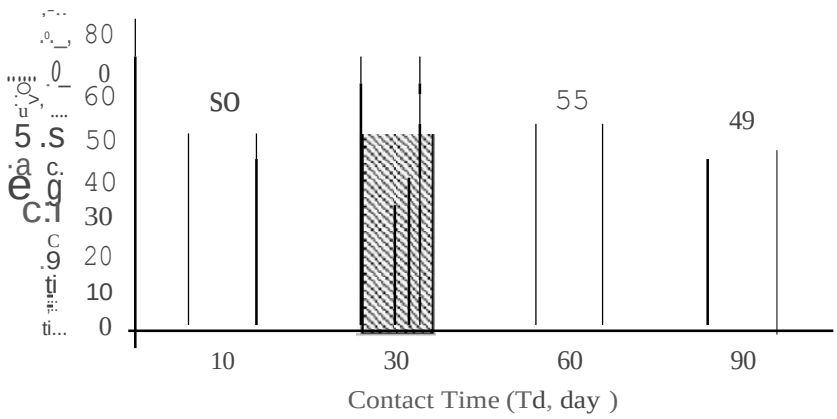


Figure 6. Efficiency of Functional Group Intensity (%) until Day-90

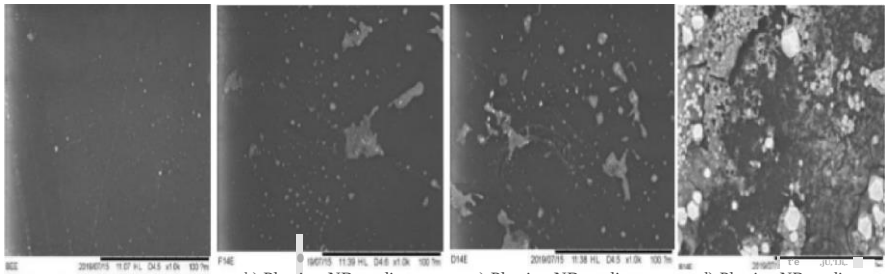
Contrary to expectation, after 30 days of incubation period, the efficiency of functional group removal did not improve until Day-90 (Figure 6). Seventy-five percent (v/v) mixed-cultured bacteria as biodegradator was apparently insufficient to improve degradation efficiency. Although bacteria can still be found on Day-90, the density was reduced 70%. The enzyme produced by mixed-cultured bacteria was seemingly not suitable with LLDPE sample as substrate. The role of enzyme in this process was as a biocataJyst which acted in accelerating chemical reactions without reacting. However, enzyme works specifically, like lock and key, whereas the catalyst substrate should be suitable with the type of enzyme. According to [12], [14], the enzyme produced by bacteria varies in several species of bacteria. *Brevibacillus spp.* is known to degrade polyethylene because it produces protease

enzyme, while *Pseudomonas spp.* produced hydrolase, esterase, and lipase. This was supported by [13], [8] which explained that plastic biodegradation by microorganisms occurred due to hydrolysis or oxidation process by the enzyme owned by microorganism to breakdown polymer substance, aerobicaJly or anaerobically.

Low efficiency of LLDPE removaJ can aJso be caused by inappropriate culture batch condition, which lead to ineffective contact between mixed-cultured bacteria and sample. Furthermore, the availability of nutrient in growth media kept decreasing until Day-90. One of the factors that affected biodegradation process is a component of a substrate or the size of a substrate. Biodegradation process will occur faster in a simpler substrate making molecules or smaJler substrate size. Otherwise, a more complex molecules and larger substrate requires longer time to decompose or degrade [6], [14]. Further studies are needed with the addition of co-substrate in a continuous culture to ensure nutrient availability until the end of observation period.

3.3. **Scanning Electron Microscope (SEM) Analysis**

LLDPE sample aJong with 75% (v/v) mixed-cultured bacteria incubated for 30 days at 30°C and pH 7 was reported to have efficiency of 5.47% and 70.67% according to gravimetry and FTIR analysis, respectively. Afterwards, SEM analysis was conducted to confirm whether there were morphological changes in LLDPE plastic sample surface.



a) Plastic + Nutrient Broth (NB) media

b) Plastic+ NB media+ IO% (vi,•) mixed-rnlnired bacteria

c) Plastic+ NB media+ 50% (viv) mixed-clllrnred bacteria

d) Plastic+ NB media+ 75% (vi,•) mixed-clltllred bacteria

Figure 7. **Morphological Changes of LLDPE Sample Surface at 30°C, pH** 7

Figure 7 visuaJly depicted morphologicaJ changes on LLDPE plastic surface, from smooth, non-porous to damage with fine pores on the surface. Incomplete biodegradation process seemed to occur by mixed-cultured bacteria which were suspected to utilize the plastic as carbon or nutrient source for their growth. The loss of 5.47% plastic weight during 30 days of incubation showed that decomposition or degradation of LLDPE plastic occurred very slowly because morphologicaJ changes only occurred on the plastic surface. Physically, the LLDPE sample had not completely broken down on Day-90. Slow biodegradation process may be due to linear low-density polyethylene (LLDPE) is a synthetic polymer consisted of molecules with linear polyethylene with monomer ethylene long chain (C 2H4) with 0.90-0.94 g/cm^3 density [5], [7]. Other than that, plastic is a substance or substrate foreign to biologicaJ system, thus produced resistance due to unsuitabiJity of substrate with ava.iJable enzyme [9], [10], [14] Biofilm layer consists of microorganism, 80-95% water, inorganic particles, and 85-98% extracellular

polymer substance that came from organic materials. The formation of microorganism cells on polymer surface as biofilm is known as biofouling [8], [12].

4. Conclusion

Mixed-cultured *Pseudomonas aeruginosa* and *Brevibacterium sp.* in controlled environment on all variations of temperature and pH can degrade LLDPE sample, although the process was very slow. The highest degradation based on removal efficiency from lost weight and efficiency of functional group intensity reduction were each 5.47o/c and 70.67% and occurred when 75% of mixed-cultured bacteria was added as degradator, and environmental condition was set to 30 °C and pH 7. Degradation did not increase until Day-90. This may be due to reduced nutrients and inappropriate culture batch condition. Therefore, further studies should be conducted with the addition of co-substrate in continuous culture to ensure nutrient availability until the end of observation period.

Acknowledgements

The authors would like to thank Directorate for Research and Community Services as well as birectorate General for Strengthening Research and Development at the Ministry of Research, Technology, and Higher Education fJJonesia for funding this study through Prime University Basic Research Grant Program (Penelitian Dasar Unggulan Perguruan Tinggi-PDUPT) 2019/2020.

Refe ces

ll) F. Alshehrei, "Biodegradation of Synthetic and Natural Plastic by Microorganisms", Journal of Applied & ·ronmental Microbiology, vol. 5, no. 1, **(2017),** pp. 8-19.

[2] S. K. Mohan, T. Srivastava, "Microbial Deterionation and Degradation of Polymeric Materials", J. , ·ochem., vol. 2, no. 4, **(2010).** pp. 210-215.

[3] R. Usha, T. Sangeetha, M. Palaniswamy, "Screening of Polyethylene Degrading Microorganisms from Garbage Soil", **Libyatt,nc.** Res. Ceo. J. Intl., vol. 3, no. 4, **(2011),** pp. 200-204.

[41 R. 0. Asriza, P. Janiar, "Photodegradation of High Density Polyethylene Containing Oxo-regradation Additives" Ind. J. Chem. Res., *vol.* 4, no. 2, (2017), pp. 402-405.

[5] B. M. Kyaw, R. Champakalakshmi, M. K. Sakharkar, C. S. Lim, 9- Sakharkar, "Biodegradation of Low Density Polythene (LOPE) by Pseudomonas Species", Indian Journal of Microbiology, vol. 52, no. 3, **(2012),** pp. 411-419.

[61 T. I. Poznyak, 0. I. Chairez, A. S. Poznyak, "Biodegradation", in Ozonation and Biodegradation in Environmental Engineering. Tatyana Poznyak, Jorge Isaac Chairez Oria, Alex Poznyak (Eds.), fl'**sterdam:** Elsevier, **(2019),** pp. 353-388.

[7] H. Rajandas, S. Parimannan, K. Sathasivam, M. Ravichandran, L. S. Yin, "A Novel FTIR-ATR Spetro,copy Based Tecnique for the Estimation of Low-Density Polyethylene B10degradat10n", Polymer Testing, vol. 3, no. 8, **(2012),** pp. 1094-1099.

[&J R.M. Donlan, "Biofilms: Microbial Life on Surfaces", Emerging Infectious Diseases, vol. 8, no. 9, **(2002),** pp. 881-890.

[9] K. Eunike, A. Rinanti, R. Ratnaningsih, "Potentialof Indigenous Bacteria to Remove Cyanide with Variations of Contact Time and Tem erature" MATEC Web of **Conferelll** vol. 197, **(2018),** pp. 1-4.

[10] R. M. Maier, "Bactenal Growth", 10 Environmental M1crob1olog1cal. Pepper, I. L., Gerba, C. P., & Gentry. T. **J.ws.),** Massachusetts: Academic Press, (2015), pp. 37-56.

[11) V. Yunar, Evaluasi Biodegradabilitas Plastik Berbahan Dasar Campman Pati dan Polietilen Menggunakan ASTM G21-09: Uji Mikroorganisme dan Uji Lapangan. Skrip,i, Universitas Indonesia, .Ok, **(2011).**

[12] H. Bhardwaj, R. Gupta, A. Tiwari, ..Microbial Population Associated with Plastic Degradation", Scientific Reports. vol. 1, no. 272, **(2012},** pp. 272-274.

[t3] S. Kumar P. M. Das L. J. Rebecca S. Sham1ila, "Isolation and identification ofLDPE degrading fungi from municipal solid waste", Journal of Chemical and Pham1aceutical Research, *vol*. S, no. 3, **(2013),** - 78-81.

[14] J. Godheja, S. K. Shekhar, S. A. Siddiqui, D.R. Modi, "Xenobiotic Compounds Present in Soil and Water: A Review on Remediation Strategies", Journal of Environmental and Analytical Toxicology, vol. 6,no.5,(2016),pp. l-18.

Potential of Linear Low-Density Polyethlene (LLDPE) Plastic Degradation by Mixed-Cultured Bacteria in Controlled Environment

ORIGINALITY REPORT

12%	9%	8%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	pubs.sciepub.com Internet Source	1%
2	tel.archives-ouvertes.fr Internet Source	1%
3	M.M. Ghangrekar, S.M. Sathe, I. Chakraborty. "In situ bioremediation techniques for the removal of emerging contaminants and heavy metals using hybrid microbial electrochemical technologies", Elsevier BV, 2020 Publication	1%
4	Elena Radu, Sorina Mitrea, Delia Patroi, Andreea Voina, Hermina Moscaliuc, Iosif Lingvay. "Biocorrosion and biodeterioration of some materials used in electrical engineering", 2016 Diagnostic of Electrical Machines and Insulating Systems in Electrical Engineering (DEMISEE), 2016 Publication	1%

5	Kartikey Kumar Gupta, Deepa Devi. "Characteristics investigation on biofilm formation and biodegradation activities of Pseudomonas aeruginosa strain ISJ14 colonizing low density polyethylene (LDPE) surface", Heliyon, 2020 Publication	1%
6	N A Lieswito, A Rinanti, M F Fachrul. "Removal of heavy metal (Cu2+) by immobilized microalgae biosorbent with effect of temperature and contact time", Journal of Physics: Conference Series, 2019 Publication	1%
7	www.ijrte.org Internet Source	1%
8	ijrdo.org Internet Source	1%
9	www.koleksiskripsi.com Internet Source	<1%
10	dspace.kpfu.ru Internet Source	<1%
11	sinta3.ristekdikti.go.id Internet Source	<1%
12	Submitted to Air Academy High School Student Paper	<1%

13	docshare.tips Internet Source	<1%
14	ojs3.unpatti.ac.id Internet Source	<1%
	Miriam Ahuactzin-Pérez, Saúl Tlecuitl-Beristain, Jorge García-Dávila, Ericka Santacruz-Juárez et al. "A novel biodegradation pathway of the endocrine-disruptor di(2-ethyl hexyl) phthalate by Pleurotus ostreatus based on quantum chemical investigation", Ecotoxicology and Environmental Safety, 2018 Publication	<1%
	Fuad Ameen, Mohamed Moslem, Sarfaraz Hadi, Ahmed E. Al-Sabri. "Biodegradation of diesel fuel hydrocarbons by mangrove fungi from Red Sea Coast of Saudi Arabia", Saudi Journal of Biological Sciences, 2016 Publication	<1%
17	www.mdpi.com Internet Source	<1%
18	Liu, Liyan, Yujie He, Huimin Lu, Maoqing Wang, Changhao Sun, Lixin Na, and Ying Li. "Metabonomic analysis of urine from rats after low-dose exposure to 3-chloro-1,2-propanediol using UPLC–MS", Journal of Chromatography B, 2013. Publication	<1%

19	Submitted to University of Sheffield Student Paper	<1%
20	ejournal2.undip.ac.id Internet Source	<1%
21	Submitted to Asociacion Escuelas Lincoln Student Paper	<1%
	K Lois, B Iswanto, A Rinanti. " Delignification and determination of sugar concentration in fertilizer as the preliminary process of bioethanol production by ", Journal of Physics: Conference Series, 2019 Publication	<1%
	Elena Stoleru, Elena Gabriela Hitruc, Cornelia Vasile, Lăcrămioara Oprică. "Biodegradation of poly(lactic acid)/chitosan stratified composites in presence of the Phanerochaete chrysosporium fungus", Polymer Degradation and Stability, 2017 Publication	<1%
	I.A. Saidi, N. Efendi, R. Azara, L. Hudi. " Indigenous technology in utilizations and handlings of palmyra palm (L.) sap and its quality from two regions of East Java ", IOP Conference Series: Materials Science and Engineering, 2018 Publication	<1%

	Elena Mastalygina, Ivetta Varyan, Natalya Kolesnikova, Maria Isabel Cabrera Gonzalez, Anatoly Popov. "Effect of Natural Rubber in Polyethylene Composites on Morphology, Mechanical Properties and Biodegradability", Polymers, 2020 Publication	<1%
26	e-sciencecentral.org Internet Source	<1%
27	www.gssrr.org Internet Source	<1%
28	Submitted to Universidade de Sao Paulo Student Paper	<1%
	M. Karthika, Nitheesha Shaji, Athira Johnson, M. Santhosh Neelakandan, Deepu A. Gopakumar, Sabu Thomas. "Biodegradation of Green Polymeric Composites Materials", Wiley, 2019 Publication	<1%
	Mohd. Shahnawaz, Manisha K. Sangale, Avinash B. Ade. "Bioremediation Technology for Plastic Waste", Springer Science and Business Media LLC, 2019 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		