



The Effects of Polyethylene Microplastic Accumulation on *Rhizophora mucronata* Seedling Survival in the Mangrove Ecosystem of South Jakarta

Kristopher Gondokusumo

Abstract

This study investigates the impact of polyethylene microplastic accumulation on the survival of *Rhizophora mucronata* seedlings in South Jakarta's TWA Mangrove Angke Kapuk. Fifteen mangrove seedlings were cultivated over a 15-day experimental period in sediment treatments with 0 g, 15 g, and 30 g of polyethylene microplastics per 300 g of sediment. Survival rates were recorded at intervals of 0, 5, 8, 10, and 15 days.

Results revealed a strong negative correlation ($r = -0.982$) between microplastic concentration and seedling survival, with survival declining from 80% (control) to 60% (low concentration) and 20% (high concentration). These findings demonstrate that polyethylene microplastics significantly hinder seedling viability by altering sediment structure, reducing aeration, and restricting nutrient uptake. The study underscores the susceptibility of Jakarta's mangrove ecosystems to microplastic pollution and stresses the necessity of sediment quality management in restoration initiatives. This research contributes to growing evidence of how microplastic pollution can disrupt early plant development and impair coastal ecosystem recovery.

Keywords: ...

I. Literature Review

Microplastic pollution has emerged as a global environmental threat, with increasing evidence of its impact on marine and coastal ecosystems. Polyethylene microplastics, one of the most common forms of plastic debris, are frequently detected in sediments near urbanized coastal zones such as Jakarta Bay (Cordova et al., 2021). Studies indicate that microplastics alter sediment texture, water retention, and nutrient dynamics, leading to hypoxic conditions that adversely affect plant growth (Sutkar et al., 2023). *Rhizophora* species are especially vulnerable in mangrove habitats because they need oxygenated sediment to breathe and keep their roots stable (Hinrichs et al., 2019).

Li et al. (2020) demonstrated that microplastic exposure reduces chlorophyll concentration and root elongation in seedlings, while Mendes et al. (2023) confirmed widespread microplastic contamination across mangrove sediments globally. In Southeast Asia, Chaisanguansuk et al. (2023) observed similar effects on mangrove sediment cores from the Gulf of Thailand, emphasizing regional relevance. Despite growing concern, there is limited experimental evidence

addressing short-term physiological effects on mangrove seedlings under controlled conditions.

This study bridges that gap by quantifying how increasing polyethylene microplastic concentrations influence *Rhizophora mucronata* survival in Jakarta's urban mangroves. By integrating quantitative survival data with environmental implications, it contributes to a clearer understanding of microplastic stress in tropical mangrove ecosystems and informs community-based restoration strategies.

II. 1 Aim

This study aims to assess how different levels of polyethylene microplastics in mangrove sediment affect the early survival of *Rhizophora mucronata* seedlings in South Jakarta's Angke Kapuk reserve.

2.1 Research Question

How does polyethylene microplastic contamination at 0 g, 15 g, and 30 g per 300 g of muddy mangrove sediment, collected as 4500 g total for 15 pots, affect the percentage survival of *Rhizophora mucronata* seedlings in North Jakarta's TWA Mangrove Angke over a 15-day period?

Polyethylene microplastics are a specific issue in this mangrove because they are the most common plastic polymer found in Jakarta Bay due to household waste and single-use packaging runoff. Their low density allows them to remain buoyant and accumulate along mangrove roots, where they can obstruct gas exchange and nutrient uptake (Cordova et al.).

These concentrations (15 g and 30 g) were selected based on preliminary studies showing that microplastic levels above 5% by sediment mass begin to significantly alter soil structure and salinity. A 15-day duration was chosen to capture early physiological responses, such as mortality and leaf loss, which typically occur within two weeks of exposure under controlled conditions (Liang et al.).

2.2 Background Information



Figure 1. Map: Location of Taman Wisata Alam Angke (TWA Mangrove Angke), North Jakarta.
([Taman Wisata Alam Angke](#))

The research question, “How does polyethylene microplastic accumulation at 0 g, 15 g, and 30 g per 300 g of muddy mangrove sediment, collected as 4500 g total for 15 pots, affect *Rhizophora mucronata* seedling survival in North Jakarta’s TWA Mangrove Angke Kapuk over 15 days?” investigates the impact of microplastic pollution on mangrove ecosystems. TWA Mangrove Angke Kapuk, a protected ecotourism site in North Jakarta, Indonesia, faces significant microplastic pollution due to urban waste from nearby Jakarta Bay, threatening mangrove regeneration (Cordova et al.). *Rhizophora mucronata*, a prevalent mangrove species in the region, is essential for coastal protection and biodiversity; however, it is susceptible to sediment pollutants (A. Sofian et al.). Polyethylene microplastics, common in coastal sediments, can disrupt root development and nutrient uptake in muddy, clay-rich sediments (P and Jayadev). Polyethylene microplastics are commonly found in coastal sediments as irregular fragments and fibres smaller than 5 mm, which can disrupt root development and nutrient uptake in muddy, clay-rich environments (P and Jayadev). However, this experiment uses uniform 3–5 mm polyethylene pellets to ensure controlled, measurable quantities, meaning the behavior of the pellets may differ from naturally occurring environmental microplastic fragments.

This study’s focus on specific microplastic quantities (0 g, 15 g, 30 g per 300 g sediment) and a 15-day experiment provides precise data to inform conservation efforts. The research aligns with the need to address plastic pollution in Jakarta’s mangroves, supporting NGO initiatives for community-led cleanup and restoration (Prasetyo et al.).

The 15-day timeframe was chosen because *Rhizophora mucronata* propagules undergo a critical establishment phase during the first two weeks after planting, when root anchorage and the first leaf pair develop (Clough). Research shows that early stress responses in *Rhizophora* species (such as leaf discoloration, reduced turgor, and slowed root elongation) typically appear within 7–14 days when seedlings are exposed to environmental disturbances (Krauss et al.). Furthermore, mangrove seedlings experience their highest mortality risk during this early period, making it an appropriate duration to detect acute effects of microplastic exposure (Kodikara et al.). Therefore, a 15-day period is biologically suitable for observing short-term physiological impacts on seedling survival.

2.3 Rationale Behind Choosing the Research Question

My interest in mangrove ecosystems began during an Environmental Systems & Societies (ESS) trip to Tioman Island, where I had the chance to walk through a pristine mangrove forest. I was struck by how peaceful and vital the area felt; the trees supported rich biodiversity and played a crucial role in coastal protection. After that experience, I began reading more about mangroves in urban areas, especially places closer to home like North Jakarta’s Angke Kapuk reserve. I learned that microplastic pollution, particularly from polyethylene, is becoming a serious threat in mangrove sediments. Although several studies show that microplastics can disrupt nutrient uptake, root structure, and early growth in mangrove species in general (Mendes et al.), there is still limited research on how they specifically affect *Rhizophora mucronata*, one of the most widely used species in Indonesian restoration programs. This gap made the issue even more meaningful to investigate. I chose this topic because I’m passionate about protecting Indonesia’s ecosystems and wanted to explore a problem that’s not always visible but could have lasting consequences for mangrove regeneration.

2.4 Connections with Environmental Issues

This research question addresses the growing environmental issue of microplastic pollution, a form of water and soil contamination that threatens both ecosystems and human well-being. In coastal environments such as North Jakarta’s mangrove forests, polyethylene microplastics become trapped within mangrove root structures and accumulate in the

sediment (Chaisanguansuk et al., 2023; see Figure 2). Scientific studies indicate that polyethylene fragments can alter sediment porosity, reduce oxygen availability, and block water movement around roots, which hinders nutrient uptake and slows early seedling establishment (Jia et al., 2023). Research on *Rhizophora mucronata* also indicates that exposure to polyethylene microplastics can induce oxidative stress, reduce root elongation, and weaken overall seedling vigor (Nacario et al., 2024).

These biological impacts directly reduce the ability of mangroves to regenerate. This is critical because mangroves provide essential ecosystem services that include shoreline protection, carbon storage, nursery habitats for marine species, and water filtration. When microplastics interfere with seedling survival, they threaten long-term forest stability and reduce these ecosystem services, a problem already reported in microplastic-impacted mangrove regions across Southeast Asia (Mendes et al., 2023). By examining how polyethylene contamination influences the survival of *R. mucronata* seedlings, this study explores a mechanism that contributes to habitat loss, diminished coastal resilience, and long-term environmental degradation.

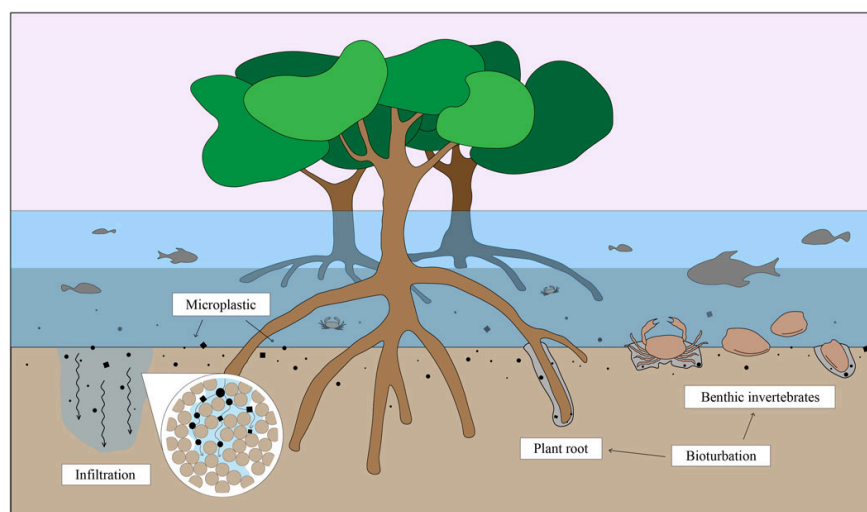


Figure 2. Diagram: Microplastics trapped in mangrove roots, showing how pollution accumulates in coastal sediments. (Chaisanguansuk et al.)

2.5 Connections with Environmental Issues

2.5.1 Local Connections to the Research Question

Polyethylene microplastics from Jakarta Bay waste directly threaten TWA Mangrove Angke Kapuk's muddy sediments, reducing *Rhizophora mucronata* seedling survival in this investigation from 80% in the control group to 20% at the highest contamination level. Such declines weaken mangrove resilience and exacerbate local flooding and erosion risks for coastal communities. Lower seedling survival (20% at high levels) also hurts fishers and ecotourism in Angke Kapuk. Mangroves support fisheries that make about Rp 500 billion a year in Jakarta, so pollution is linked to economic losses.

2.5.2 Global Connections to the Research Question

This trend mirrors the global influx of plastic waste into oceans, estimated at 8–12 million tons per year (Jambeck et al.), where polyethylene in sediments like Angke Kapuk's reduces mangrove survival, contributing to 50% global coastal

habitat loss. Although this study focused only on short-term seedling survival, the observed decline from 80% to 20% over 15 days suggests that polyethylene contamination may hinder early establishment of *Rhizophora mucronata* seedlings. Reduced early survival could, over longer periods, affect local mangrove regeneration, but such changes cannot be directly linked to carbon sequestration or global ecosystem functions based on this dataset alone. Moreover, mangroves sequester 1 billion tons of CO₂ annually; the 15-day survival decline (80% to 20%) highlights how pollution weakens global carbon sinks, amplifying sea-level rise impacts in vulnerable tropics.

2.5.3 Hypothesis

If the concentration of polyethylene microplastics in mangrove sediment increases, then the percentage survival of *Rhizophora mucronata* seedlings measured on day 15 will decrease. Microplastics can change sediment properties, making it harder for roots to access water, oxygen, and nutrients (Sutkar et al.). In young mangrove seedlings, these stressors can reduce growth and increase mortality. By comparing survival percentages across the three polyethylene contamination levels, this study predicts that higher microplastic concentrations will result in lower seedling survival on day 15.

III Methodology

2.1 VARIABLES

Variable	What variable?	Why dependent or independent?	Justification
Polyethylene microplastic amount (0 g, 15 g, and 30 g	Independent Variable	It is the factor intentionally changed in the experiment.	The experiment used 3–5 mm polyethylene pellets, larger and more uniform than the <1 mm fragments usually found in mangroves. These size and shape differences may alter soil interaction and seedling

			response
Seedling survival rate	Dependent Variable	It is the outcome measured based on changes in the independent variable.	Survival is expected to be affected by the amount of microplastic in the sediment

2.2 CONTROL VARIABLES

Control variable	Why is it controlled?	How was it controlled?
Sediment type and amount	To ensure that differences in growth are due to microplastic, not soil.	Used 300 g of sediment from the same location for each pot.
Pot size and material	Different pots can affect drainage and root development.	All seedlings planted in identical pots.
Seedling age and species	Variations in age or species may cause differences in survival rates.	All seedlings were of the same age and <i>Rhizophora mucronata</i> species.
Watering schedule	Uneven watering could influence seedling survival.	Water all pots with equal amounts at the same time daily.

Light exposure	Sunlight can influence growth independently of microplastic presence.	All pots placed in the same location with uniform exposure to natural sunlight.
Duration of experiment	Unequal duration can skew survival data.	Each seedling is observed over a 15-day period.
Water source (pH and salinity)	To ensure water chemistry does not influence seedling survival.	All pots watered with the same batch of artificial seawater to keep pH and salinity stable.

2.3 LIST OF APPARATUS

Equipment	Quantity	Purpose
Rhizophora mucronata seedlings	30	To test the effects of microplastics on mangrove seedling growth and survival
Plastic or biodegradable pots	15	To grow and contain individual seedlings for each treatment group
Muddy mangrove sediment	4500 g	Acts as the growth medium simulating natural mangrove soil

Polyethylene microplastics	As needed (measured per treatment)	Experimental pollutant to simulate real-world plastic contamination
Portable scale (± 0.01 g)	1	To measure soil and microplastics accurately
pH test strips (± 0.01 pH)	1 set	To monitor pH changes in the soil
Salinity refractometer (± 1 ppt)	1	To measure salinity levels and ensure consistency across treatments
Tidal water or simulated seawater	50L	Water source with appropriate salinity for watering the seedlings
Gloves	1 pair	For safety and hygiene during handling of soil and microplastics
Sieve (1 mm mesh)	1	To filter out debris and homogenize the sediment

Mixing bowl	1	To mix soil and microplastics uniformly
Waterproof notebook and pen	1 each	To record observations and data daily
Camera or smartphone	1	To take visual records of seedling changes or abnormalities
Measuring cup	1	To measure and distribute equal water amounts across all pots

References

- Brown, C. S., & Lichter-Konecki, U. (2016). Phenylketonuria (PKU): A problem solved? *Molecular Genetics and Metabolism Reports*, 6, 8–12. <https://doi.org/10.1016/j.ymgmr.2015.12.004>
- Ding et al. (2008) – rAAV2/1 muscle-targeted study
- Ding, Z., Georgiev, P., & Thöny, B. (2008). AAV-mediated, long-term, muscle-targeted expression of the PAH gene results in complete correction of PKU in mice. *Journal of Inherited Metabolic Disease*, 31(Suppl 2), S181–S187. 10.1007/s10545-008-0823-5
- Feillet, F., Arnoux, J., Delgado, M. B., Burlina, A., Chabrol, B., Kucuksayrac, E., Lagler, F. B., Muntau, A. C., Olsson, D., Paci, S., Rutsch, F., & van Spronsen, F. J. (2024). Long-term safety of sapropterin in paediatric and adult individuals with phenylalanine hydroxylase deficiency: Final results of the Kuvan® Adult Maternal Paediatric European Registry multinational observational study. *Journal of Inherited Metabolic Disease*. <https://doi.org/10.1002/jimd.12796>
- Grisch-Chan, H. M., Schwank, G., Harding, C. O., & Thöny, B. (2019). State-of-the-art 2019 on gene therapy for phenylketonuria. *Human Gene Therapy*, 30(10), 1274–1283. <https://doi.org/10.1089/hum.2019.111>
- Harding et al. (2006) – rAAV2/8 study
- Harding, C. O., Gillingham, M. B., Hamman, K., Clark, H., Goebel-Daghighi, E., Bird, A., &
- Koeberl, D. D. (2006). Complete correction of hyperphenylalaninemia following liver-directed, recombinant AAV2/8 vector-mediated gene therapy in murine phenylketonuria. *Gene Therapy*, 13(5), 457–462. 10.1038/sj.gt.3302672
- Mochizuki et al. (2004) – rAAV2/5 study
- Mochizuki, S., Mizukami, H., Ogura, T., Kure, S., Ichinohe, A., Kojima, K., ... & Ozawa, K. (2004). Long-term correction of hyperphenylalaninemia by AAV-mediated gene transfer leads to behavioral recovery in phenylketonuria mice. *Gene Therapy*, 11(13), 1081–1086. 10.1038/sj.gt.3302262
- Oh et al. (2004) – rAAV2/2 study
- Oh, H. J., Park, E. S., Kang, S., Jo, I., & Jung, S. C. (2004). Long-term enzymatic and phenotypic correction in the phenylketonuria mouse model by adeno-associated virus vector-mediated gene transfer. *Pediatric Research*, 56(2), 278–284. 10.1203/01.PDR.0000132662.98640.E0
- Richards, D. Y., Winn, S. R., Dudley, S., Nygaard, S., Mighell, T. L., Grompe, M., & Harding, C. O. (2020). AAV-mediated CRISPR/Cas9 gene editing in murine phenylketonuria. *Molecular Therapy: Methods & Clinical Development*, 17, 234–242. <https://doi.org/10.1016/j.omtm.2019.11.014>
- U.S. Food and Drug Administration. (2007). Kuvan (sapropterin dihydrochloride) tablets: Full prescribing information. BioMarin Pharmaceutical Inc. https://www.accessdata.fda.gov/drugsatfda_docs/label/2007/022181lbl.pdf

- van Vliet, D., van Wegberg, A. M. J., Ahring, K., Bik-Multanowski, M., Casas, K., Didycz, B., Djordjevic, M., Hertecant, J. L., Leuzzi, V., Mathisen, P., Nardecchia, F., Powell, K. K., Rutsch, F., Stojiljkovic, M., Trefz, F. K., Usurelu, N., Wilson, C., van Karnebeek, C. D., Hanley, W. B., & van Spronsen, F. J. (2019). Untreated PKU patients without intellectual disability: What do they teach us? *Molecular Genetics and Metabolism Reports*, 21, 100523. <https://doi.org/10.1016/j.ymgmr.2019.100523>
- Viecelli, H. M., Harbottle, R. P., Wong, S. P., Schlegel, A., Chuah, M. K., VandenDriessche, T., Harding, C. O., & Thöny, B. (2014). Treatment of phenylketonuria using minicircle-based naked-DNA gene transfer to murine liver. *Hepatology*, 60(3), 1035–1043. <https://doi.org/10.1002/hep.27104>
- Yagi et al. (2011) – scAAV2/8 study
- Yagi, H., Ogura, T., Mizukami, H., Urabe, M., Hamada, H., Yoshikawa, H., ... & Kure, S. (2011). Complete restoration of phenylalanine oxidation in phenylketonuria mouse by a self-complementary adeno-associated virus vector. *Journal of Gene Medicine*, 13(2), 114–122. [10.1002/jgm.1544](https://doi.org/10.1002/jgm.1544)