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Effect of Land Use within Watershed Boundary on the Types of Microplastics Observed in Surface Water

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Abstract:
Due to exposure to their chemical components, microplastics (<5mm) are byproducts of plastic degradation that can be harmful to the environment and human health. Microplastics, one of which is in the watershed, will be present due to human activity-related irresponsible discharge of plastic waste into the environment. The watershed's use of the land has an impact as well. This research aims to analyze how different land use patterns affect the types of microplastics that have been observed. This research's methodology is quantitative and includes techniques for spatial, statistical, and chemical analysis. In the Ciujung watershed, polyethylene (PE), polypropylene (PP), and polyester microplastics were observed according to the study's findings. The type of microplastic observed was likely brought on by local activities. On agricultural land, plantations, and settlements, fertilization, irrigation, and other human activities may contribute to microplastic contamination. The vast amount of plastic bags and bottles that are left behind are either immediately dumped into the Ciujung Watershed by the locals or carried away by the flow of activities on the land, where they eventually degrade into microplastics.

Keywords: *Microplastics, land use, watershed, polyethylene (PE), polypropylene (PP), polyester*

1. Introduction

Due to the ease and wide range of applications in different applications, plastic is the most commonly used material (Borg et al., 2022). Barnes et al. (2009) stated in their study that plastic also harms the environment. Since plastic can degrade into smaller microscopic particles known as microplastics, this concern exists (Pagano et al., 2019). Microplastics, also known as simply 'particles <5mm in size,' are the byproducts of plastic degradation, according to Moore et al. (2001). Polidoro et al. (2022) found that microplastics can be hazardous to the environment and human health due to their chemical composition. According to Yu et al. (2020), microplastics include a significant quantity of carbon, which is either inert or difficult to react with and decomposes slowly. Rillig et al. (2019) claimed that the chemical composition of microplastics is characterized as a harmful compound in the same debate regarding the chemical makeup of microplastics.

Microplastics can be distributed due to their small size (Blettler et al., 2018). Microplastics will, therefore, eventually build up in the environment, with the watershed being one of them (Lebreton et al., 2017). Because of that distribution phenomenon, the watershed's streams can become contaminated with microplastics. Besides that, global modeling estimates that rivers carry between 1.15 and 2.41 million tons of plastic debris, eventually making their way into the ocean (Lebreton & Andrady, 2019). This is supported by a World Bank (2021) report that claims rivers are responsible for more than 80% of the debris coming from land sources that end up in the ocean, mostly plastic. Additionally, it was mentioned that between 0.34 and 0.71 million tonnes of plastic debris that is improperly managed will end up in waterways annually. This quantity comes from debris intentionally placed into rivers or plastic debris transported by water from the mainland, including landfills. According to a study by Omoyajowo et al. (2021) and Wu et al. (2022), human behavior and anthropogenic activities that carelessly dispose of plastic into the environment are to blame for the existence of debris. The possibility for microplastic pollution will result from this, especially in highly urbanized areas (Jambeck et al., 2015; Kunz et al., 2023).

There are several watersheds in the country of Indonesia (Garg et al., 2018). With a population of 273.5 million in 2020 (Central Bureau of Statistics, 2021), people will likely engage in a lot of activity in watersheds, increasing the likelihood of producing microplastics. The Ciujung watershed is one of those that could become contaminated by microplastics. The Ciujung Watershed is a vital facility for the public, according to the Department of Environment and Forestry of Banten Province (2017). This is due to the Ciujung Watershed's continued widespread use by the population for socioeconomic purposes, including its status as a water body that receives agricultural and industrial wastewater. In the Ciujung watershed, there has been an upstream-to-downstream shift in land use over the past ten years, as can be seen in satellite imaging. The main changes were in agriculture and plantations, which changed from being plantations to settlements and industries. In a study, Kurniawan et al. (2021) claimed that land conversion and urbanization are sources of microplastic pollution. To reduce microplastic pollution in the Ciujung watershed, it is also crucial to identify the point and non-point sources of microplastics at the local scale. Several studies, including those by Kabir et al. (2021), Zhang, Peng, et al. (2022), and Zhang, Wang, et al. (2022), in addition to the ones already mentioned, have also revealed that land use has an impact on microplastic pollution.

In layman's terms, anthropogenic activities that carelessly discharge plastics into the environment are the cause of the presence of microplastics. The possibility for increasing microplastic contamination is then subsequently triggered by the land conversion that takes place within the boundaries of the watershed. As a result, the objective of this research will be to analyze how different land use types affect the types of microplastics that have been observed. The Ciujung watershed, which is located in the westernmost part of the island of Java, Indonesia, will be used as a case study. The results of the research are anticipated to be useful in various initiatives aimed at preventing pollution, overuse, and harm to environmental ecosystems.

2. Methodology

2.1. Location and Sample

The research's methodology and approach are both quantitative. The Ciujung watershed, which has a river length of 147.2 km from Lebak Regency to Serang Regency, was the site of this research. This is based on the idea that the river must be viewed as a natural unit composed of upstream, middle, and downstream areas to examine land use for microplastic types (Suganda et al., 2009). In the same discussion, it was also underlined that watershed management was carried out by the philosophy of "One Watershed, One Management Plan" when the Watershed Management Workshop was created and held in Yogyakarta in October 1985. Geographically, the Ciujung Watershed is located at 5°57'14” S - 6° 4'20" S and 106° 01'00" E - 106° 29'03" E.

The abiotic component (surface water) in the Ciujung watershed is the research's population. In this research, there were four sampling sites—referred to as stations—representing the upstream, middle, and downstream sections of the river. The Department of Environment and Forestry of the Banten Province conducted the sampling using the purposive sampling approach, adapting to the routine monitoring point for water parameters by BBWS C3 (an integrated management unit under the Ministry of Public Works and Public Housing, Indonesia). Table 1 shows the locations of the sampling stations and their distances from downstream. Following SNI 03-7016-2004, which outlines procedures for sampling in the context of monitoring water quality in a river basin area, water samples were collected from the four stations. At each station, water will be drawn from the left, right, and middle sides of the river using the integrated sample approach. Half of the river's depth is the depth of the water sample.

Sampling Locations		Coordinate		Distance from Downstream
Station 1	Bojongmanik	S: 6°34’32.79”	E: 106°10’9.39”	115,34 km
Station 2	Rangkas II Bridge	S: 6°20’54.48”	E: 106°14’50.66”	58,2 km
Station 3	Pamarayan	S: 6°15’38.67”	E: 106°16’41.42”	41,92 km
Station 4	Undar-Andir	S: 6°9’11.10”	E: 106°18’35.42”	24,12 km

Table 1: Microplastic Sampling Station
Source: Department of Environment and Forestry of the Banten Province (2021)

2.2. Research Analysis Method

Primary and secondary data collected cross-sectionally were the types of data used in this research. With the use of the Fourier Transform Infra Red - Attenuated Total Reflectance (FTIR-ATR), quantitative and qualitative chemical analysis was performed to determine the type of microplastic. The wet peroxide method used by Kovač Viršek et al. (2016) and Prata et al. (2019) will be used to treat the microplastics obtained from the station before being observed, whereas Hu et al. (2022) previously modified the Fenton procedure. Meanwhile, the type of land use is data that includes land use for various purposes, including industry, agriculture, and animal husbandry. Cross-tabulation statistical analysis was used to determine the frequency (number) of the data that possessed particular features. Additionally, the spatial analysis will improve the application of this analysis. According to Brunsdon & Comber (2015), normal statistical analysis cannot adequately account for the complexity of spatial processes and spatial data. Hence, it is insufficient for analyzing observations in geographic space. The research was conducted using ArcGIS 10.8 and SPSS v.20 software.

3. Result and Discussion

3.1. Types of Microplastic Observed

Microplastics are made of many kinds of polymers and have different kinds of molecular structures (Rochman et al., 2019). According to Strungaru et al. (2019), all polymers are made of repeating monomers that serve as the structure of the polymer. The physical and chemical properties of plastics are determined by this backbone structure, which also distinguishes between different types of polymers. According to data from PlasticEurope (2020), polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polyurethane, polyethylene terephthalate (PET), and polystyrene are generally the polymers that are produced and used most around the global. The FTIR instrument, namely FTIR-ATR in this observation, can be utilized to determine the type of microplastic. The few samples served as the basis for choosing the instrument. Table 2 shows the findings of the FTIR-ATR observation at the four stations in the Ciujung watershed based on the bonds created. The peaks' C-H and C=C bonds, as well as the patterns they produced, are the main points of focus. The reason for focusing on these bonds is that polymers, the primary structure of microplastic structures, have them as a component.

Location	Absolute Threshold	Sensitivity	Position (cm^{-1})	Intensity	Chemical Bond	
Station 1	77.487	66.000	2914.880	10.594	C-H	Alkanes
			2847.660	16.579	C-H	Alkanes
			1645.450	70.414	C=C	Alkene (mono substitute)
Station 2	85.487	61.000	1408.040	74.684	C-H	Alkanes
			845.990	75.121	C=C	Alkene (tri substitute)
			793.240	79.946	C-H	1,2,3 tri substitute
Station 3	74.185	70.000	2914.740	7.488	C-H	Alkanes
			2847.620	11.038	C-H	Alkanes
Station 4	73.460	66.000	295.090	30.078	C-H	Alkanes
			2871.920	43.728	C-H	Alkanes
			2837.740	46.541	C-H	Aldehydes

Table 2: Peaks and Observed Chemical Bonds
Source: Integrated Laboratory Research Center Universitas Indonesia (2023)

Following table 2, some peaks are sufficiently prominent to identify the presence of C-H and C=C bonds. The range of wavelengths and intensities formed in this observation was interpreted using the IR spectrum table provided by Sigma Aldrich. Overall, it can be said that, except station 2, C-H and C=C bonds are typically discovered at positions or wavelengths greater than 1500 cm-1. At station 2, these bonds can be seen at about 1500 cm-1 in wavelength. The OMNIC 9.26 software was then employed to determine the specific type of microplastic that was discovered, as opposed to only chemical bonds and peaks. Based on the literature it has, this software will search the index and find any matches. Table 3 shows the analyses' findings using OMNIC 9.26. According to the information provided, polyethylene and polypropylene are the two most common types of microplastics to be found in the Ciujung Watershed. 42.86% of all types of microplastics discovered were made of polyethylene. These compounds are found following polystyrene at 19.05%, other types at 4.76%, and polypropylene at 33.33%. According to data from PlasticEurope (2020), the most extensively produced and consumed types of polymers globally are polypropylene (PP) and polyethylene (PE), and these are the types of microplastics discovered in the Ciujung watershed. Therefore, it can be claimed that there is a correlation between the production of plastic, its use, and its disposal into the environment, which eventually results in the generation of microplastics.

Location	Index	Match	Types of Microplastics	Library
Station 1	2788	94,78	Polyethylene, aged cordage, + propylene	HR Comprehensive Forensic FTIR Collection
	2792	94,62	Polyethylene (LLDPE)	
	2796	94,59	Polyethylene (SPP)	
	2614	94,37	Polyethylene + Acrylic Acid	
Station 2	2735	93,78	Polyester, bicomponent fiber	HR Comprehensive Forensic FTIR Collection
	1152	93,24	Polyester, diameter 9μm	
	1650	92,45	Poly(cyclohexane diol terephthalate)	
	2771	92,38	Polyester, a special type of PET	
	2750	92,33	Polyester, trevira 120	
Station 3	2788	95,60	Polyethylene, aged cordage, + propylene	HR Comprehensive Forensic FTIR Collection
	2792	95,58	Polyethylene (LLDPE)	
	2796	95,48	Polyethylene (SPP)	
	2614	95,09	Polyethylene + Acrylic Acid	
Station 4	41	90,61	Polypropylene, atactic	Hummel Polymer Sample Library
	38	85,49	Polypropylene, syndiotactic	
	2815	84,95	Polypropylene (dengan adiktif)	HR Comprehensive Forensic FTIR Collection
	867	84,29	Reinforce concentrate (polyethylene + polypropylene)	
	2941	84,25	Propylmatte (propylene)	
	3310	84,21	Solar active polypropylene	
	3757	83,79	Polypropylene	

Table 3: Types of Microplastics Observed
Source: Primary Data Analysis

3.2. Effect of Land Use on the Type of Microplastic

The Ciujung Watershed, the largest watershed in Banten Province, is crossed administratively by Lebak and Serang Regency, two districts. The discussion will be split into two segments, the Lebak Regency and Serang Regency, as a result of the analysis that was done. Figure 1 shows not only a spatial visualization of the land uses landscape for both segments, but also the sort of microplastics observed. Polyethylene (PE) plastic was found at station 1, and polystyrene (PS) at station 2, according to the previous observation. Social spaces in plantations and communities are probably what produced the microplastics at station 1. In the Ciujung Watershed, a lot of plastic packaging and bottles are dumped by the people or left on plantations, where they are eventually carried away by streams and degraded into microplastics. According to research by Zhang, Wang, et al. (2022), polyethylene (PE) and polypropylene (PP) were the two predominant types of microplastics found on plantations. In addition to plantations and settlements, the type of land utilized for dry fields and bushes also has a significant impact on the prevalence of microplastics. Several studies demonstrate that microplastics are pervasive despite the lack of human activity, including in tropical ecosystems and the wild areas of North America (Álvarez-Lopeztello et al., 2021; Brahney et al., 2020). The occurrence is believed to have occurred due to atmospheric scale movement. According to a study by Dong et al. (2022), microplastics can migrate up to 800 km in the atmosphere. At station 2, it is evident that settlements dominate the type of land use. According to Kunz et al. (2023), urban or residential areas, particularly those with a high population density, are a source of microplastic pollution. According to a study by Bi et al. (2023) and Park & Kim (2022), residential areas frequently have polyolefin microplastics (PE and PP) prevalent. However, polyester microplastic looks like the type found in this observation. This may be because locals in the Ciujung Watershed still frequently wash their clothes, which allows for the detection of this form of microplastic to exist. Polyester is a material that is frequently used in textiles, particularly in the form of polyethylene terephthalate (PET) (J. Yu et al., 2022)

The types of microplastics observed at stations 3 and 4 in the Serang Regency segment spatially correlate with land use, as shown in figure 1. Waters (ponds, rivers, and lakes), forests, industries, plantations, settlements, rice fields, bushes, and moors or fields are among the different land-use types that may be seen in figure 1. Rice fields, settlements, and plantations were found to be the main land uses in the area of stations 3 and 4. This suggests that irrigation, fertilizing, and other human activities should all contribute to the creation of microplastics. Polyethylene (PE) and polypropylene (PP) types of microplastics are most commonly observed on agricultural land, plantations, and populated areas (Zhang, Wang et al., 2022). In particular, PE is the raw material for plastic films frequently used in agricultural and plantation activities, and polypropylene is the raw material for plastic bags and straps (L. Yu et al., 2021). The sort of microplastic observed in this research, where PE and PP were found at stations 3 and 4, is consistent with this.

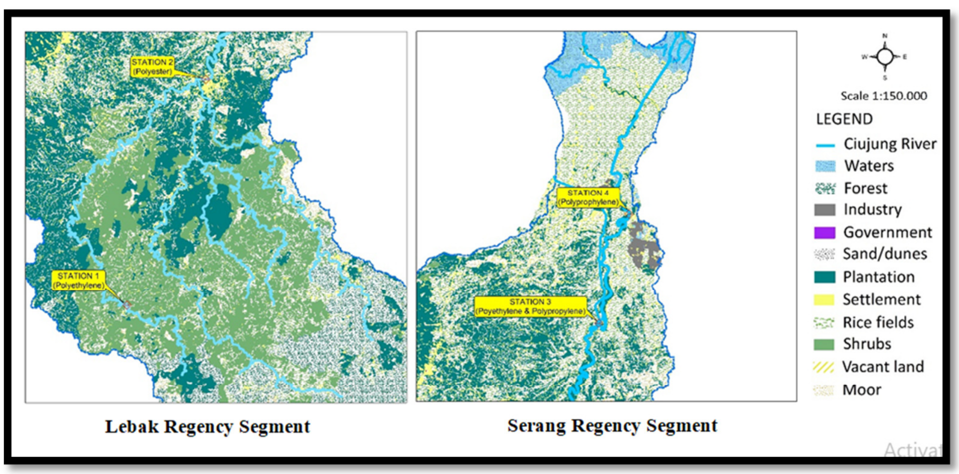

Figure 1: Land Use within Watershed Boundary and Observed Types of Microplastics
Source: Primary and Secondary Data Analysis

4. Conclusion

It is established that one of the factors contributing to the contamination of surface water with microplastics present within the boundaries of the watershed is land use. According to the observation, microplastics made of polyester, polyethylene, and polypropylene were found in the Ciujung watershed. 42.86 percent of all types of microplastics discovered were made of polyethylene. Following polystyrene at 19.05 percent, other types at 4.76 percent, and polypropylene at 33.33 percent, these structures have been found. According to the variety of plastics that are commonly produced and consumed widely, it can be said that the types of microplastics detected in the Ciujung watershed are polyethylene and polypropylene. The type of microplastic found was likely brought on by local activities. On agricultural land, plantations, and settlement, fertilization, irrigation, and other human activities may contribute to microplastic contamination. The Ciujung Watershed will eventually get contaminated with microplastics from the vast amount of plastic bags and bottles that are left behind and eventually taken away by the flow from the land activities or those that are dumped there by the locals.

5. References

i. Álvarez-Lopeztello, J., Robles, C., & del Castillo, R. F. (2021). Microplastic pollution in a neotropical rainforest, savanna, pine plantations, and pasture soils in lowland areas of Oaxaca, Mexico: Preliminary results. *Ecological Indicators*, *121*(April), 107084. https://doi.org/10.1016/j.ecolind.2020.107084

ii. Central Bureu Statistics. (2021). *Perkiraan Penduduk Beberapa Negara (Juta Jiwa)*. https://www.bps.go.id/indikator/indikator/view_data/0000/data/290/website_12/1

iii. Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). *Accumulation and fragmentation of plastic debris in global environments*. *April 2014*. https://doi.org/10.1098/rstb.2008.0205

iv. Bi, D., Wang, B., Li, Z., Zhang, Y., Ke, X., Huang, C., Liu, W., Luo, Y., Christie, P., & Wu, L. (2023). Occurrence and distribution of microplastics in coastal plain soils under three land-use types. *Science of the Total Environment*, *855*(July 2022). https://doi.org/10.1016/j.scitotenv.2022.159023

v. Blettler, M. C. M., Abrial, E., Khan, F. R., Sivri, N., & Espinola, L. A. (2018). Freshwater plastic pollution: Recognizing research biases and identifying knowledge gaps. *Water Research*, *143*, 416–424. https://doi.org/10.1016/j.watres.2018.06.015

vi. Borg, K., Lennox, A., Kaufman, S., Tull, F., Prime, R., Rogers, L., & Dunstan, E. (2022). Curbing plastic consumption : A review of single-use plastic behaviour change interventions. *Journal of Cleaner Production*, *344* (September 2021), 131077. https://doi.org/10.1016/j.jclepro.2022.131077

vii. Brahney, J., Hallerud, M., Heim, E., Hahnenberger, M., & Sukumaran, S. (2020). Plastic rain in protected areas of the United States. *Science*, *368*(6496), 1257–1260. https://doi.org/10.1126/science.aaz5819

viii. Brunsdon, C., & Comber, L. (2015). An Introduction to R for Spatial Analysis & Mapping. In R. Rojek (Ed.), *SAGE Publications Ltd*.

ix. Department of Environment and Forestry of Banten Province. (2017). *Pengelolaan DAS Provinsi Banten*. https://dlhk.bantenprov.go.id/read/article/264/Pengelolaan-DAS-Provinsi-Banten.html

x. Dong, Y., Bao, Q., Gao, M., Qiu, W., & Song, Z. (2022). A novel mechanism study of microplastic and As co-contamination on indica rice (Oryza sativa L.). *Journal of Hazardous Materials*, *421*(May 2021), 126694. https://doi.org/10.1016/j.jhazmat.2021.126694

xi. Garg, T., Hamilton, S. E., Hochard, J. P., Plous, E., & Talbot, J. (2018). *(Not so) gently down the stream : River pollution and health in*. *92*, 35–53.

xii. Hu, K., Zhou, P., Yang, Y., Hall, T., Nie, G., Yao, Y., Duan, X., & Wang, S. (2022). Degradation of Microplastics by a Thermal Fenton Reaction. *ACS ES and T Engineering*, *2*(1), 110–120. https://doi.org/10.1021/acsestengg.1c00323

xiii. 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. *Marine Pollution*, *September 2014*, 768–771.

xiv. Kabir, A. H. M. E., Sekine, M., Imai, T., Yamamoto, K., Kanno, A., & Higuchi, T. (2021). Assessing small-scale freshwater microplastics pollution, land-use, source-to-sink conduits, and pollution risks: Perspectives from Japanese rivers polluted with microplastics. *Science of the Total Environment*, *768*, 144655. https://doi.org/10.1016/j.scitotenv.2020.144655

xv. Kovač Viršek, M., Palatinus, A., Koren, Š., Peterlin, M., Horvat, P., & Kržan, A. (2016). Protocol for Microplastics Sampling on the Sea Surface and Sample Analysis. *Journal of Visualized Experiments : JoVE*, *118*, 1–9. https://doi.org/10.3791/55161

xvi. Kunz, A., Schneider, F., Anthony, N., & Lin, H. (2023). Microplastics in rivers along an urban-rural gradient in an urban agglomeration : Correlation with land use, potential sources, and pathways ☆. *Environmental Pollution*, *321*(January), 121096. https://doi.org/10.1016/j.envpol.2023.121096

xvii. Kurniawan, S. B., Said, N. S. M., Imron, M. F., & Abdullah, S. R. S. (2021). Microplastic pollution in the environment: Insights into emerging sources and potential threats. *Environmental Technology and Innovation*, *23*, 101790. https://doi.org/10.1016/j.eti.2021.101790

xviii. Lebreton, L., & Andrady, A. (2019). Future Scenarios of Global Plastic Waste Generation and Disposal. *Palgrave Communications*, 1–11. https://doi.org/10.1057/s41599-018-0212-7

xix. Lebreton, L., Zwet, J. van der, Damsteeg, J., Slat, B., Andrady, A., & Reisser, J. (2017). River plastic emissions to the world's oceans. *Nature Communications*, *8*, 1–10. https://doi.org/10.1038/ncomms15611

xx. Moore, C. J., Moore, S. L., Leecaster, M. K., & Weisberg, S. B. (2001). *A Comparison of Plastic and Plankton in the North Paci ® c Central Gyre*. *42*(12), 1297–1300.

xxi. Omoyajowo, K., Raimi, M., Waleola, T., & Odipe, O. (2021). *Public Awareness, Knowledge, Attitude and Perception on Microplastics Pollution Around Lagos Lagoon*. *2*(24), 35–46.

https://doi.org/10.31471/2415-3184-2021-2(24)-35-46

xxii. Pagano, M., Vazzana, I., Gentile, A., Caracappa, G., & Faggio, C. (2019). Hematological and biochemical parameters in Sea turtles (Caretta caretta) after stranding. *Regional Studies in Marine Science*, *32*, 100832. https://doi.org/10.1016/j.rsma.2019.100832

xxiii. Park, S. Y., & Kim, C. G. (2022). A comparative study on the distribution behavior of microplastics through FT-IR analysis on different land uses in agricultural soils. *Environmental Research*, *215*(P2), 114404. https://doi.org/10.1016/j.envres.2022.114404

xxiv. PlasticEurope. (2020). *Plastics – the Facts 2020: An analysis of European Plastics Production, Demand, and Waste Data*. https://www.plasticseurope.org

xxv. Polidoro, B., Lewis, T., & Clement, C. (2022). Heliyon A screening-level human health risk assessment for microplastics and organic contaminants in near-shore marine environments in American Samoa. *Heliyon*, *8* (September 2021), e09101. https://doi.org/10.1016/j.heliyon.2022.e09101

xxvi. Prata, J. C., da Costa, J. P., Duarte, A. C., & Rocha-Santos, T. (2019). Methods for sampling and detection of microplastics in water and sediment: A critical review. *TrAC - Trends in Analytical Chemistry*, *110*, 150–159. https://doi.org/10.1016/j.trac.2018.10.029

xxvii. Rillig, M. C., Lehmann, A., de Souza Machado, A. A., & Yang, G. (2019). Microplastic effects on plants. *New Phytol 223*, 1066–1070. https://doi.org/10.1111/nph.15794

xxviii. Rochman, C. M., Brookson, C., Bikker, J., Djuric, N., Earn, A., Bucci, K., Athey, S., Huntington, A., McIlwraith, H., Munno, K., Frond, H. de, Kolomijeca, A., Erdle, L., Grbic, J., Bayoumi, M., Borrelle, S. B., Wu, T., Santoro, S., Werbowski, L. M., … Hung, C. (2019). Rethinking microplastics as a diverse contaminant suite. *Environmental Toxicology and Chemistry*, *38*(4), 703–711. https://doi.org/10.1002/etc.4371

xxix. Strungaru, S., Jijie, R., Nicoara, M., Plavan, G., & Faggio, C. (2019). Trends in Analytical Chemistry Micro- (nano) plastics in freshwater ecosystems: Abundance, toxicological impact, and quantification methodology. *Trends in Analytical Chemistry*, *110*, 116–128. https://doi.org/10.1016/j.trac.2018.10.025

xxx. Suganda, E., Yatmo, Y. A., & Atmodiwirjo, P. A. (2009). Pengelolaan Lingkungan dan Kondisi Masyarakat Pada Wilayah Hilir Sungai. *Makara Human Behavior Studies in Asia*, *13*(2), 143. https://doi.org/10.7454/mssh.v13i2.255

xxxi. World Bank. (2021). *Indonesia: Visi 2024 Menuju Ketahanan Air*.

xxxii. Wu, Y., Chen, X., Wen, L., Li, Z., Peng, M., Wu, H., & Xie, L. (2022). Science of the Total Environment Linking human activity to spatial accumulation of microplastics along mangrove coasts. *Science of the Total Environment*, *825*, 154014. https://doi.org/10.1016/j.scitotenv.2022.154014

xxxiii. Yu, J., Tang, D., Wang, S., He, L., & Pathira Arachchilage, K. R. L. (2022). Spatial Distribution and Composition of Surface Microplastics in the Southwestern South China Sea. *Frontiers in Marine Science*, *9*(February), 1–14. https://doi.org/10.3389/fmars.2022.830318

xxxiv. Yu, L., Zhang, J. di, Liu, Y., Chen, L. Y., Tao, S., & Liu, W. X. (2021). Distribution characteristics of microplastics in agricultural soils from the largest vegetable production base in China. *Science of the Total Environment*, *756*, 1–9. https://doi.org/10.1016/j.scitotenv.2020.143860

xxxv. Yu, Q., Hu, X., Yang, B., Zhang, G., Wang, J., & Ling, W. (2020). Chemosphere Distribution, abundance, and risks of microplastics in the environment. *Chemosphere*, *249*, 126059. https://doi.org/10.1016/j.chemosphere.2020.126059

xxxvi. Zhang, Y., Peng, Y., Xu, S., Zhang, S., Zhou, G., Yang, J., Li, H., & Zhang, J. (2022). Distribution characteristics of microplastics in urban rivers in Chengdu city: The influence of land-use type and population and related suggestions. *Science of the Total Environment*, *846*(July), 157411. https://doi.org/10.1016/j.scitotenv.2022.157411

xxxvii. Zhang, Y., Wang, K., Chen, W., Ba, Y., Khan, K., Chen, W., Tu, C., Chen, C., & Xu, L. (2022). Effects of land use and landscape on the occurrence and distribution of microplastics in soil, China. *Science of the Total Environment*, *847*(June). https://doi.org/10.1016/j.scitotenv.2022.157598