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GRADUATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

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RESEARCHING THE APPEARANCE AND DENSITY OF MICROPLASTIC IN WASTEWATER, SURFACE WATER OF THE SAI GON - DONG NAI RIVER, AND PROPOSING MITIGATION SOLUTIONS

Major: **Environmental Engineering**

Code: **9520320**

THE SUMMARY OF ENVIRONMENTAL ENGINEERING DOCTORAL THESIS

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Supervisor 2: Prof. PhD. NGUYEN THI HUE

Reviewer 1: …

Reviewer 2: …

Reviewer 3: ….

The thesis shall be defended in front of the Thesis Committee at Vietnam Academy of Science And Technology - Graduate University of Science And Technology, at .... hour......, date...... month.......year 2025

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INTRODUCTION

1. The urgency of the thesis

Plastic is a synthetic material that is widely used in everyday life due to its properties, cost-effectiveness, durability, low weight and ease of production. Microplastics have been commonly detected in the water and sediment of many rivers globally and even in treatment systems from wastewater plants. In the aquatic environment, microplastics exist mainly in the form of fibers, fragments and particles, which form from the breakdown of larger plastic objects. Currently, qualitative data regarding the morphology, dimensions, and coloration of microplastics, as well as their trends within riverine water environments, remains significantly scarce. Investigations into the removal of microplastics through wastewater treatment processes has not received much attention. The majority of existing scientific literature predominantly addresses microplastics found in seawater or estuarine environments, while the presence of microplastics in inland surface waters is seldom discussed.

The Saigon - Dong Nai river system serves as the primary source of domestic water for residents of Ho Chi Minh City and its surrounding provinces. There is currently a lack of comprehensive information regarding the identification, density, distribution, and characteristics of microplastics within the Saigon - Dong Nai river system. Therefore, the dissertation topic "***Researching the appearance and density of microplastic in wastewater, surface water of the Sai Gon- Dong Nai river, and proposing mitigation solutions***" was carried out. The dissertation employs evaluation techniques that include the application of data analysis algorithms and programming in the R 4.2.0 environment to analyze scientific data related to microplastics. This analysis is complemented by technical methods such as electron microscopy and FTIR infrared spectroscopy. Through this approach, the research has successfully identified and characterized the density, distribution, and morphology of microplastics. This represents a relatively novel area ofresearch in Vietnam. The findings of this dissertation offer valuable preliminary data for environmental managers regarding the current levels of microplastics present in the surface water of the Saigon - Dong Nai rivers and in domestic wastewater. Additionally, the research presents a comprehensive overview of technological approaches aimed at the removal of microplastics, as well as recycling strategies that promote a circular lifecycle for plastics. This work seeks to reduce the release of microplastics into the environment and includes an assessment of the feasibility of the proposed solutions.

2. Research objectives of the thesis

- Apply and improve the NOAA's process for collecting and analyzing microplastic samples in seawater to the process of collecting microplastic samples in surface water, tailored to the environmental conditions in Vietnam, enhance the quantitative and qualitative analysis process for identifying microplastic particles in continental surface water samples.
- Conduct an evaluation of the density and variation of microplastic particles in the surface water of the Saigon - Dong Nai river; assess the level of microplastic contamination in the influent and effluent wastewater, along with their treatment efficiency at centralized wastewater treatment plants within the Saigon - Dong Nai river basin.
- Propose solutions to reduce microplastic particles in the continental freshwater environment, specifically in the Saigon - Dong

Nai river water.

3. Scientific and practical significance of the dissertation

The findings of this dissertation enhance the methodology for investigating microplastics in continental surface water environments and provide an overview of the current levels of microplastic pollution in wastewater and surface waters of the Saigon and Dong Nai rivers. Furthermore, these results establish a scientific foundation for managing and reducing microplastic contamination in both wastewater and river surface waters in Vietnam. On the other hand, the research findings of the dissertation are valuable for further extended studies and academic education in related fields.

4. New point of the thesis

- Investigate the changes in density, size, shape, and color of microplastics in the surface water of the Saigon - Dong Nai river based on seasonal variations and tides.
- Assess the effectiveness of removing microplastics from wastewater and propose a mechanism to eliminate microplastics from the wastewater stream using existing wastewater treatment processes.

CHAPTER 1. OVERVIEW OF RESEARCH ISSUES

Chapter 1, consisting of 20 pages, clearly outlines the urgency of the research direction, specifically focusing on microplastics, their presence in aquatic environments, and particularly their occurrence in inland rivers and wastewater treatment plants in densely populated urban areas. The goal is to assess the spatial and temporal trends of their characteristics. These topics remain relatively new, with limited research publications and few studies addressing them comprehensively. The dissertation's research approach covers a broad spatial scope, extending from upstream to downstream, including densely populated urban areas along two major rivers in southern Vietnam: the Saigon River and the Dong Nai River. Based on the evaluation of natural conditions and the existing situation, the study has improved methods for sampling microplastics in river water and wastewater, as well as refining analytical techniques and laboratory procedures for microplastic identification.

Chapter 1 provides a comprehensive review of previous studies related to the research direction of the dissertation, both domestically and internationally. The specific characteristics of plastic waste and microplastics in the study area have been clearly identified based on detailed assessments, closely linked to the research issues that the dissertation aims to address. This chapter also summarizes modern analytical methods for identifying microplastics in water samples.

The procedures for sampling river water and wastewater, as well as the extraction process for quantifying, qualifying, and identifying microplastics, were conducted following U.S. EPA Method 3540C and were further refined and developed from NOAA’s protocol for analyzing microplastics in seawater samples.

CHAPTER 2. RESEARCH METHODS

Chapter 2 consists of 26 pages and provides a detailed presentation on the selection of the research subject in the dissertation—microplastics in the Saigon–Dong Nai River water and the wastewater from treatment plants that discharge directly or indirectly into these rivers. The water sampling process and the analysis procedures for identifying microplastics were carried out based on NOAA's methodology for studying microplastics in the marine environment, which was modified, adjusted, and optimized to suit the actual conditions in Vietnam.

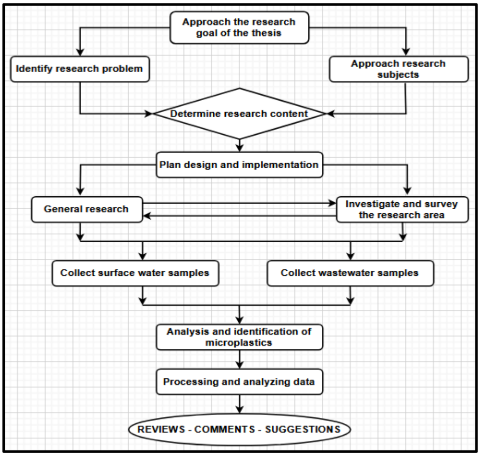


Figure 2. 1. Research diagram of the dissertation

Chapter 2 also covers the extraction of microplastics in preparation for the quantification, qualification, and identification stages, following the guidelines of US EPA Methods 3540C. Additionally, advanced analytical techniques were employed to determine the morphology, color, and size of microplastics. These included the Leica Stereoscope S6D microscope (magnification range 0.5X – 80X) combined with an HD camera for capturing appropriate images, as well as the FTIR imaging microscope Nicolet iN10 MX equipped with ATR accessories to analyze the polymer peak spectra of microplastics.

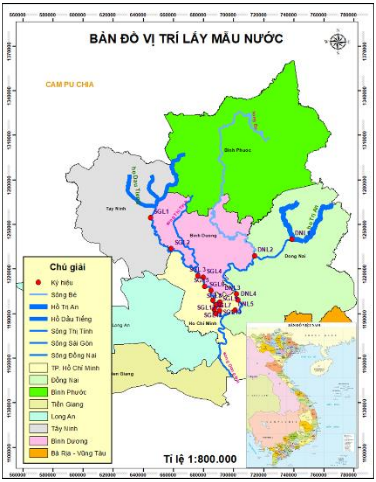


Figure 2. 2. Map of 18 surface water sampling locations

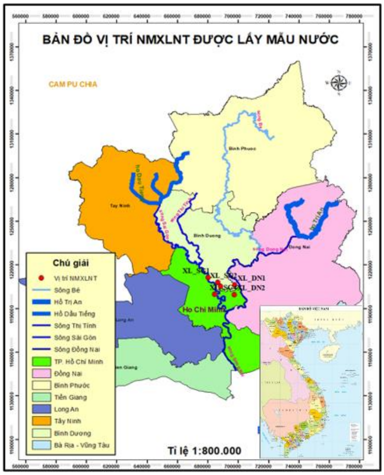


Figure 2. 3. Location of 6 wastewater treatment plants sampled

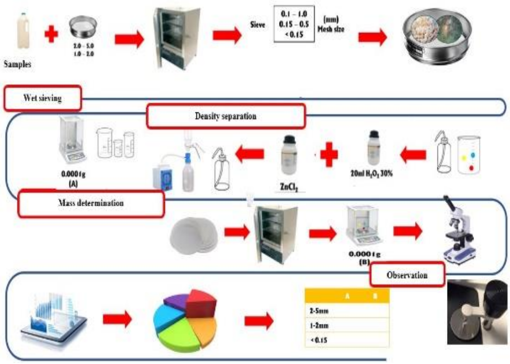


Figure 2. 4. Analytical process for determining microplastics

Additionally, the data analysis model incorporates predictive statistical algorithms such as multivariate correlation analysis, principal component analysis, cluster analysis, and regression analysis. These methods are integrated to process microplastic data and are implemented using R 4.2.0, with the support of SPSS 25.0 and Microsoft Excel on the Microsoft Office 2023 platform.

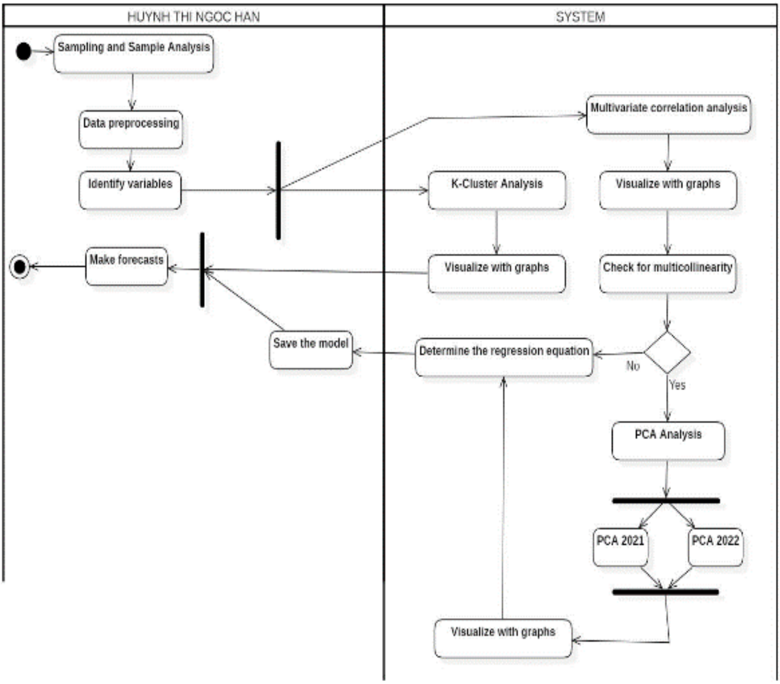


Figure 2. 5. Architecture diagram of data processing model in research

Additionally, the SWOT analysis method, the five-point Likert scale, along with expert evaluation and survey methods, were utilized to assess the feasibility of the proposed solutions in the dissertation.

CHAPTER 3. RESULTS AND DISCUSSION

3.1. Microplastics in surface water of Saigon - Dong Nai river

The results from the stereomicroscope revealed that microplastic particles come in various colors, shapes, and sizes ranging from 1 to 5 mm, primarily in the form of fibers. The water sample taken from a depth of 3-5 meters contained between 228,120,000 and 715,124,000 microplastic fibers per cubic meter. The initial findings of the research indicated that the microplastic fibers exhibited diverse morphology and colors, which were clearly observed using the Leica-Stereoscope S6D microscope (see Figure 3.1).

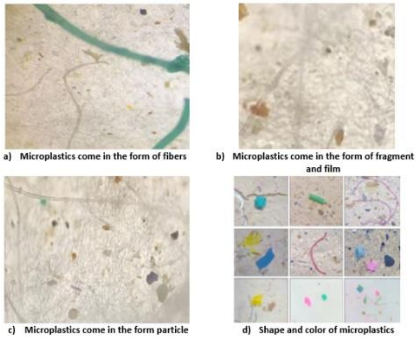


Figure 3. 1. Shape and color of microplastics in water samples recorded through Leica Stereoscope S6D microscope

3.1.1. Microplastic density

The microplastic density in 18 research sites is illustrated in Figure 3.2 and Figure 3.3. Additionally, the results of SPSS analysis correlating microplastics with tides and seasons of the year are presented in Figure 3.4 and Figure 3.5.

a) b)

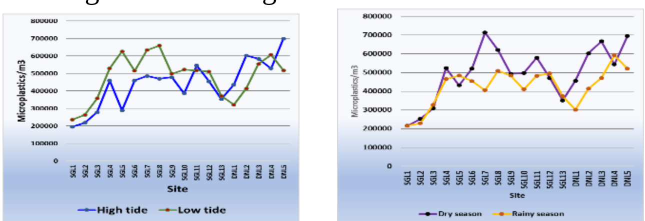
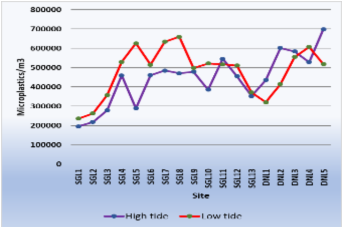
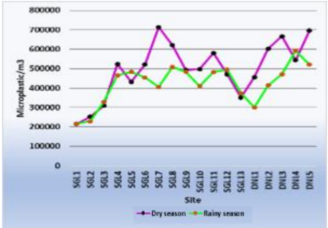


Figure 3. 2. Evolution of microplastic density in water samples of Dong Nai and Saigon rivers in 2021

a) Average density of microplastics according to tidal changes; b) Average density of microplastics according to seasonal changes of the year





a) **b)**

Figure 3. 3. Evolution of microplastic density in Dong Nai River and Saigon River in 2022

a) Average density of microplastics according to tidal changes; b) Average density of microplastics according to seasonal changes of the year

Correlations

		MuaKho	TrieuLen	TrieuXuong
MuaKho	Pearson Correlation	1	.930**	.932**
	Sig. (2-tailed)		.000	.000
	N	18	18	18
TrieuLen	Pearson Correlation	.930**	1	.734**
	Sig. (2-tailed)	.000		.001
	N	18	18	18
TrieuXuong	Pearson Correlation	.932**	.734**	1
	Sig. (2-tailed)	.000	.001	
	N	18	18	18

a) **. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		MuaMua	TrieuLen	TrieuXuong
MuaMua	Pearson Correlation	1	.717**	.707**
	Sig. (2-tailed)		.001	.001
	N	18	18	18
TrieuLen	Pearson Correlation	.717**	1	.013
	Sig. (2-tailed)	.001		.958
	N	18	18	18
TrieuXuong	Pearson Correlation	.707**	.013	1
	Sig. (2-tailed)	.001	.958	
	N	18	18	18

b) **. Correlation is significant at the 0.01 level (2-tailed).

Figure 3. 4. Microplastic correlation results at low tide, tide and season in 2021

a) Dry season; b) Rainy season

Correlations

		MuaKho	TrieuLen	TrieuXuong
MuaKho	Pearson Correlation	1	.961**	.966**
	Sig. (2-tailed)		.000	.000
	N	18	18	18
TrieuLen	Pearson Correlation	.961**	1	.857**
	Sig. (2-tailed)	.000		.000
	N	18	18	18
TrieuXuong	Pearson Correlation	.966**	.857**	1
	Sig. (2-tailed)	.000	.000	
	N	18	18	18

a) **. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		MuaMua	TrieuLen	TrieuXuong
MuaMua	Pearson Correlation	1	.933**	.933**
	Sig. (2-tailed)		.000	.000
	N	18	18	18
TrieuLen	Pearson Correlation	.933**	1	.741**
	Sig. (2-tailed)	.000		.000
	N	18	18	18
TrieuXuong	Pearson Correlation	.933**	.741**	1
	Sig. (2-tailed)	.000	.000	
	N	18	18	18

b) **. Correlation is significant at the 0.01 level (2-tailed).

Hình 3. 5. Results of correlation analysis of microplastics at high tide and low tide according to seasons in 2022

a) Dry season; b) Rainy season

*The symbol ** indicates that this pair of variables has a linear correlation at the 99% confidence level (corresponding to a significance level of 1% = 0.01).*

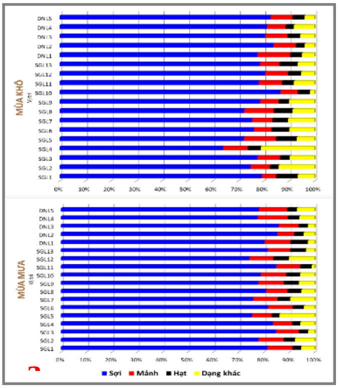
*The symbol * indicates that this pair of variables has a linear correlation at the 95% confidence level (corresponding to a significance level of 5% = 0.05).*

Microplastic concentrations ranged from 195,604 to 705,612 particles/m³ during high tide and from 234,911 to 726,196 particles/m³ during low tide. In the dry season, concentrations varied between

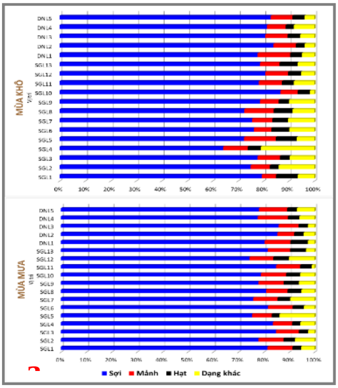
213,340 and 715,032 particles/m³, while in the rainy season, they ranged from 216,503 to 729,502 particles/m³. These findings indicate that tidal water levels are related to and influence the variations in microplastic concentrations at different locations within the river basin, with statistical significance ($p < 0.05$) (Figures 3.4 and 3.5). Specifically: i) In 2021: Dry season: A seasonal correlation was observed during high tide (Figure 3.4a). Rainy season: A seasonal correlation was observed during both low and high tides (Figure 3.4b). ii) In 2022: In both the dry and rainy seasons, a correlation was found only with high tide levels (Figures 3.5a and 3.5b).

3.1.2. Shape of microplastics

Microplastics come in three forms: fibers, fragments, and particles, while all other shapes are categorized as ‘other’ forms. The distribution ratio is shown in Figure 3.6. Figures 3.6a and 3.6b indicate that fibrous microplastics dominate the survey findings for both 2021 and 2022 (79.17% and 79.23% respectively).



a)



a)

Figure 3.6. Percentage of microplastic shapes in 2021-2022 at survey locations

a) Distribution rate of microplastic shapes in 2021; b) Distribution rate of microplastic shapes in 2022

The correlation results from SPSS are displayed in Figure 3.7 (for 2021) and Figure 3.8 (for 2022). Specifically, plastic products designed to meet human needs generated a significantly higher amount of microplastic fibers compared to other forms of microplastics in both years, with a p-value of less than 0.05. This analysis ignores other forms of microplastics due to a multicollinearity problem, as indicated by the sig values circled in blue in Figure 3.7 and Figure 3.8. The average density of microplastic fragments is slightly higher in the rainy season compared to the dry season. Variations were observed in the proportion of microplastic shapes at different sampling sites. The results of the correlation analysis of microplastic shape variables and PCA for the years 2021 and 2022 can be found in Figure 3.9 and Figure 3.10.

Correlations

		MuaKho	MPs_Soi	MPs_Manh	MPs_Hat	MPs_Khac
MuaKho	Pearson Correlation	1	.970**	.770**	.692**	.342
	Sig. (2-tailed)		.000	.000	.001	.165
	N	18	18	18	18	18
MPs_Soi	Pearson Correlation	.970**	1	.677**	.594**	.125
	Sig. (2-tailed)	.000		.002	.009	.620
	N	18	18	18	18	18
MPs_Manh	Pearson Correlation	.770**	.677**	1	.518*	.324
	Sig. (2-tailed)	.000	.002		.028	.189
	N	18	18	18	18	18
MPs_Hat	Pearson Correlation	.692**	.594**	.518*	1	.392
	Sig. (2-tailed)	.001	.009	.028		.108
	N	18	18	18	18	18
MPs_Khac	Pearson Correlation	.342	.125	.324	.392	1
	Sig. (2-tailed)	.165	.620	.189	.108	
	N	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a)

Correlations

		MuaMua	MPs_Soi	MPs_Manh	MPs_Hat	MPs_Khac
MuaMua	Pearson Correlation	1	.855**	.709**	.855**	.982**
	Sig. (2-tailed)		.000	.001	.000	.000
	N	18	18	18	18	18
MPs_Soi	Pearson Correlation	.855**	1	.757**	1.000**	.746**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	18	18	18	18	18
MPs_Manh	Pearson Correlation	.709**	.757**	1	.757**	.611**
	Sig. (2-tailed)	.001	.000		.000	.007
	N	18	18	18	18	18
MPs_Hat	Pearson Correlation	.855**	1.000**	.757**	1	.746**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	18	18	18	18	18
MPs_Khac	Pearson Correlation	.982**	.746**	.611**	.746**	1
	Sig. (2-tailed)	.000	.000	.007	.000	
	N	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).
b)

Figure 3.7. The results correlated microplastic patterns with the season in 2021

Correlations

		MuaKho	MPs_Soi	MPs_Manh	MPs_Hat	MPs_Khac
MuaKho	Pearson Correlation	1	.968**	.617**	.902**	.735**
	Sig. (2-tailed)		.000	.006	.000	.001
	N	18	18	18	18	18
MPs_Soi	Pearson Correlation	.968**	1	.427	.786**	.572*
	Sig. (2-tailed)	.000		.077	.000	.013
	N	18	18	18	18	18
MPs_Manh	Pearson Correlation	.617**	.427	1	.817**	.693**
	Sig. (2-tailed)	.006	.077		.000	.001
	N	18	18	18	18	18
MPs_Hat	Pearson Correlation	.902**	.786**	.817**	1	.817**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	18	18	18	18	18
MPs_Khac	Pearson Correlation	.735**	.572*	.693**	.817**	1
	Sig. (2-tailed)	.001	.013	.001	.000	
	N	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).
a) *. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		MuaMua	MPs_Soi	MPs_Manh	MPs_Hat	MPs_Khac
MuaMua	Pearson Correlation	1	.985**	.768**	.891**	.680**
	Sig. (2-tailed)		.000	.000	.000	.002
	N	18	18	18	18	18
MPs_Soi	Pearson Correlation	.985**	1	.705**	.820**	.563*
	Sig. (2-tailed)	.000		.001	.000	.015
	N	18	18	18	18	18
MPs_Manh	Pearson Correlation	.768**	.705**	1	.844**	.493*
	Sig. (2-tailed)	.000	.001		.000	.038
	N	18	18	18	18	18
MPs_Hat	Pearson Correlation	.891**	.820**	.844**	1	.740**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	18	18	18	18	18
MPs_Khac	Pearson Correlation	.680**	.563*	.493*	.740**	1
	Sig. (2-tailed)	.002	.015	.038	.000	
	N	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).
b) *. Correlation is significant at the 0.05 level (2-tailed).

Figure 3.8. The results correlated microplastic patterns with the season in 2022

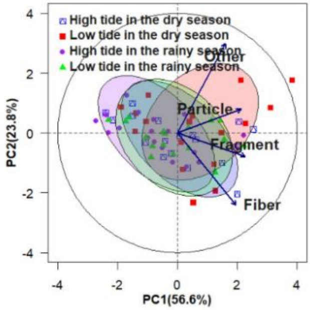


Figure 3.9. PCA analysis results for microplastic shapes during the 2021 dry season

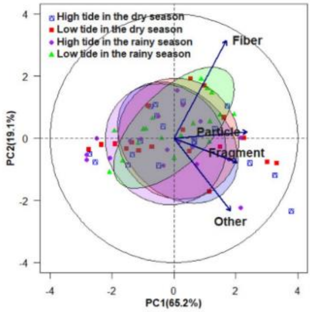


Figure 3.10. PCA analysis results for microplastic shapes during the 2022 dry season

Based on the results obtained from the PCA analysis in R language, it has been demonstrated that principal components PC1 and PC2 for both years explain more than 60-70% of the variance in the data set. Specifically, the equation for 2021 is:

PC1 = 0,49 Fiber + 0,56 Fragment + 0,53 Particle

PC2 = 0,75 Other

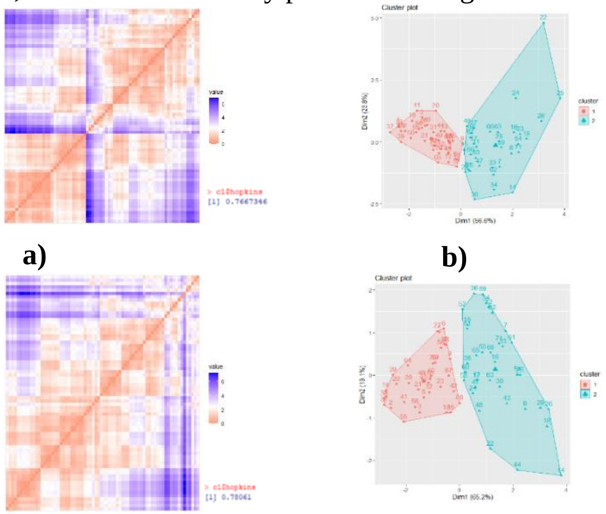
The same for 2022 is:

PC1 = 0,43 Fiber + 0,51 Fragment + 0,46 Other

PC2 = 0,52 Particle

In both seasons, the Dong Nai and Saigon rivers have high concentrations of fibrous microplastics, with 2022 showing higher levels than 2021. The study created K-Mean clusters based on the Hopkins coefficient, as depicted in Figure 3.11. The blue group and the red group exhibit similarities in microplastic morphology, explained by PC1, which accounts for 56.6% of the variance. Specifically, the morphology includes fibers (56%), fragment (with a coefficient of determination of 49%), and particle (53%)

characteristics. This is clearly illustrated in Figure 3.11b. Similarly, for 2022, the results are clearly presented in Figure 3.11d.



a) b) c) d)

Figure 3. 11. Results of K-Mean analysis based on microplastic morphology

a) Cụm liên kết theo màu (xanh dương và đỏ) trong năm 2021; b) Biểu Cluster Plot năm 2021; c) Cụm liên kết theo màu (xanh dương và đỏ) trong năm 2022; d) Biểu Cluster Plot năm 2022

3.1.3. Color of microplastics

The statistics for microplastic color are presented in Figure 3.12. The correlation results and the evolution of microplastic color according to the tide during the day using R are shown in Figures 3.13 and 3.14. Additionally, the results of the cluster analysis of microplastic color characteristics according to the sampling sites using R are displayed in Figure 3.15.

Results of the deduction in 2021

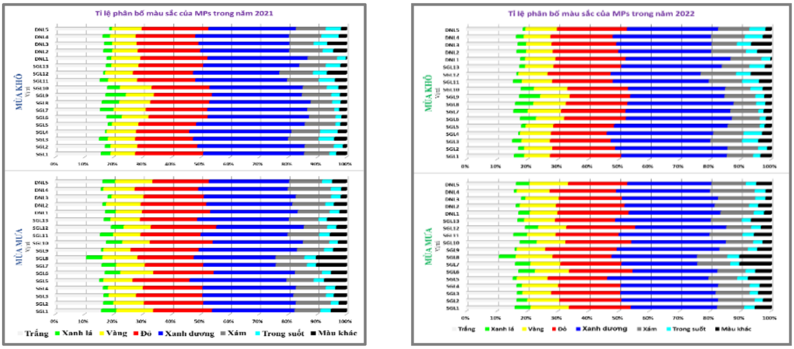
PC1 = 0,42 White+ 0,413 Yellow + 0,434 Red + 0,42 Blue + 0,39 Gray

PC2 = 0,68 Green + 0,42 Transparent + 55,3 Other

Results of the deduction in 2022

PC1 = 0,40 White + 0,38 Other

PC2 = 0,71 Green + 0,13 Yellow + 0,25 Blue + 61,9 Other



a) **b)**

Figure 3.12. Percentage of color of microplastics in 2021-2022 at survey sites

a) Microplastic color distribution rate in 2021; b) Microplastic color distribution rate in 2022

The Saigon-Dong Nai River is impacted by microplastics of various colors, including white, yellow, red, blue, and gray, throughout the year. To identify sampling sites with similar microplastic color characteristics, a cluster analysis was performed using the average microplastic color data collected during both dry and wet seasons (refer to Figure 3.13). The color cluster classifications of the sampling sites for two different years can be observed in Figure 3.13a and Figure 3.13c. It is interesting to note that similar color characteristics are categorized into different clusters, as illustrated in Figure 3.13b and Figure 3.13d.

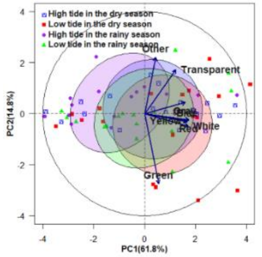


Figure 3.13. PCA analysis results for microplastic color during the 2021 dry season

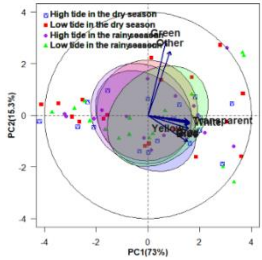
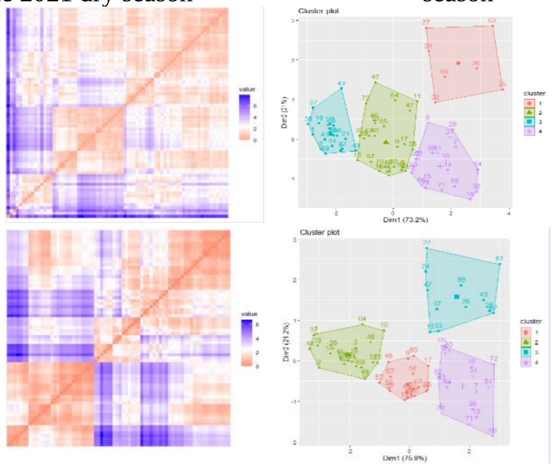


Figure 3.14. PCA analysis results for microplastic color during the 2022 dry season

a) b)



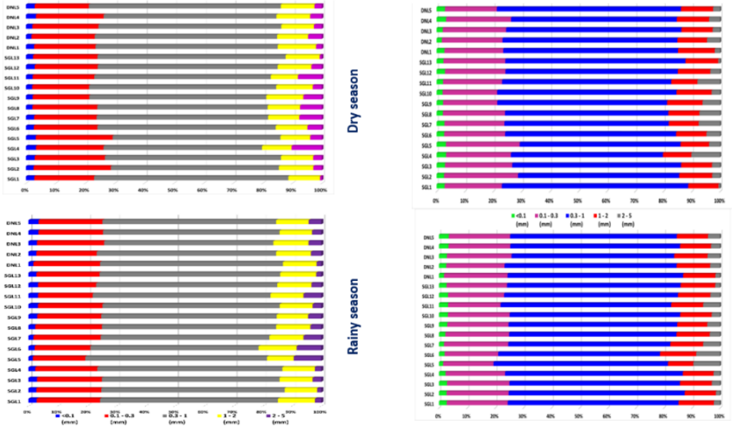
c) d)

Figure 3.15. Results of color cluster analysis of clear microplastics in 2 years 2021 – 2022

a) Link clusters by color (blue and red) in 2021; b) Cluster plot chart of 18 locations in 2021; c) Cluster links by color (blue and red) in 2022; b) Cluster plot chart of 18 locations in 2022

3.1.4. Size of microplastic

The percentage of microplastic sizes appearing at different sampling sites is illustrated in Figure 3.16.



a) **b)**

Figure 3.16. Size distribution of microplastics at locations taken in the dry and rainy seasons

a) 2021; b) 2022

During the dry season, larger microplastics (4–5 mm, 3-4 mm, 2–3 mm) are more prevalent and are projected to increase in 2022 compared to 2021.

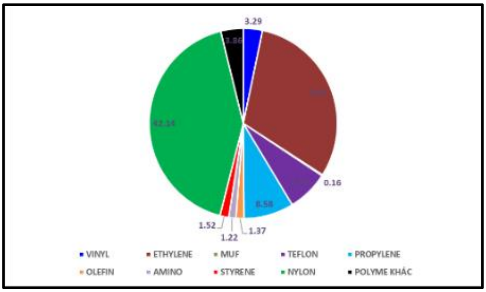


Figure 3.17. Percentage of polymers appearing in water samples of Dong Nai river and Saigon river

3.1.5. Polymer forms were discovered

A total of 100 samples were analyzed using the FTIR method combined with ART accessories to identify over 60 types of polymers. The chemical radicals ratio is illustrated in Figure 3.17.

3.2. Microplastics in wastewater from treatment plants in the Saigon - Dong Nai river basin

Research results on the average density of microplastics in the waste stream are shown in Figure 3.18

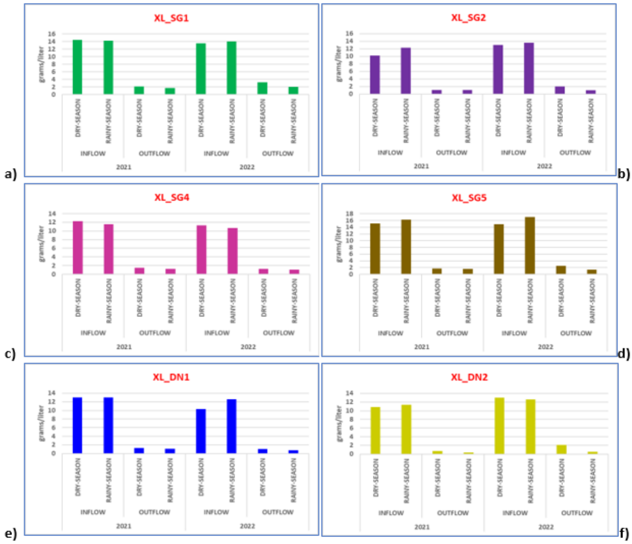


Figure 3.18. Mass density of microplastics in wastewater before and after leaving treatment plants

a) Nam Binh Duong (Thuan An); b) VSIP 1; c) Ba Bo (Dong An); d) Tham Luong – Ben Cat; e) Di An; f) Ho Chi Minh City High-Tech Park

The efficiency of removing microplastics from waste streams in wastewater treatment plants is calculated based on the density values of the inlet and outlet streams. The role of wastewater treatment technology at factories is evaluated to have an average efficiency of 89.1% in removing microplastics from the waste stream (Figure 3.19).

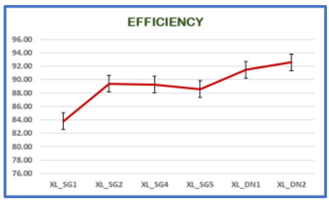


Figure 3.19. Percentage of average efficiency in removing microplastics

Figure 3.20 illustrates the correlation between processing efficiency and microplastics size, particularly showing a strong correlation (up to 0.83) for microplastics ranging from 2 mm to 3 mm (Size_3), as depicted in Figure 3.21

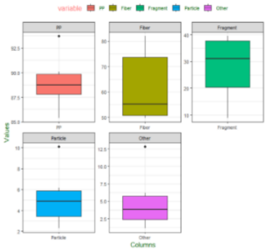


Figure 3.20. Distribution of percentage values and outliers according to density of microplastics and treatment efficiency of wastewater treatment plants

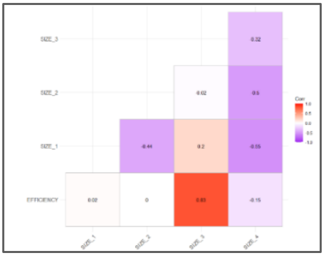


Figure 3.21. Correlation matrix between plant processing efficiency and microplastics of different sizes

More than 31 types of microplastic polymers have been discovered (Figure 3.22). During the dry season, the average mass density of microplastics ranges from 116×10^{-2} to 265×10^{-2} mg/l, and during the rainy season, it ranges from 44×10^{-2} to 187×10^{-2} mg/l. Fibrous microplastics make up the largest proportion, with frequencies ranging from 49.8% (Tham Luong - Ben Cat) to 81.96% (VSIP). Specifically, by microplastic size, size_1 accounts for 44.67% to 54.03%, size_2 accounts for 28.77% to 38.64%, size_3 accounts for 10.2% to 12.55%, and size_4 accounts for 4.72% to 14.13% (Figure 3.23).

Figure 3.22. List of microplastic polymers detected in wastewater samples using FTIR transform infrared spectroscopy

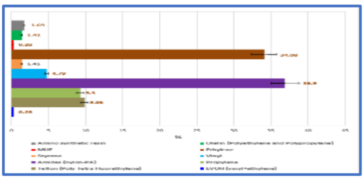


Figure 3.23. Percentage of synthetic polymers of microplastics found in wastewater samples from factories

3.3. Research results suggest solutions to reduce microplastics

3.3.1. General management solution

Strengthen mechanisms and policies to specify Party and State policies, viewpoints, and orientations, promoting improvement and innovation.

3.3.2. Proposing solutions to reduce plastic and microplastic waste

3.3.2.1. Proposing initial solutions to reduce plastic and microplastic waste

Circular economy solution for the plastic industry (Figure 3.24) with a 5-step Likert scale from 1 to 5 in Figure 3.25.

Figure 3.24. Proposed overall circular economy solution for the plastic industry to minimize the emission of plastic waste and microplastics into the environment

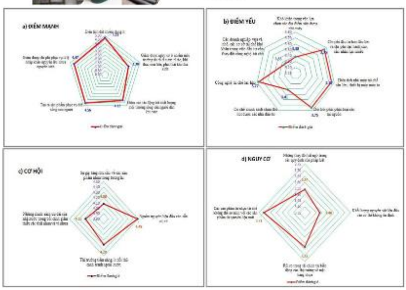


Figure 3.25. Radar spider chart of SWOT assessment in solution adoption
(a) Strengths;
(b) Weaknesses;
(c) Opportunity;
(d) Risk of challenge

3.3.2.2. Proposed technology diagram for recycling plastic waste

Based on the results of analyzing the current status of plastic waste and microplastics in the city. Ho Chi Minh City and neighboring provinces on the Saigon - Dong Nai rivers, research and propose a plastic waste recycling model The 7-step process is shown in Figure 3.26.

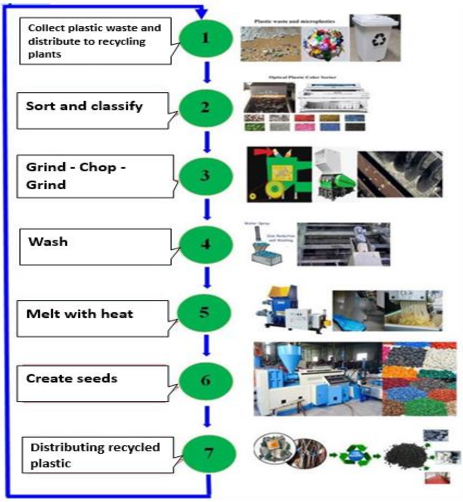
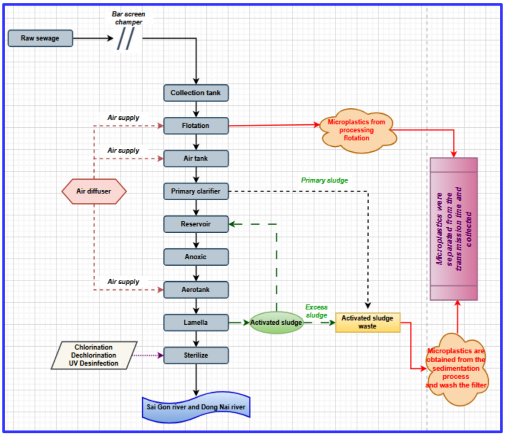


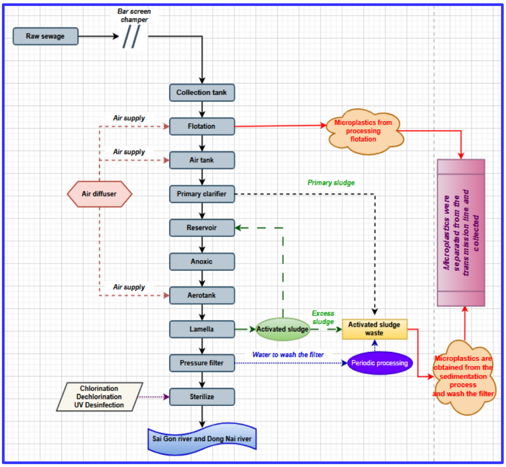
Figure 3.26. Technological process of recycling household plastic waste

3.3.3. Proposing technological solutions for wastewater treatment to reduce microplastics

Research and propose a more improved wastewater treatment technology diagram, custom built according to required capacity, output meeting QCVN 14:2008/BTNMT while achieving optimal efficiency in removing microplastics from the stream waste (Figure 3.26).



a) Treated water that meets QCVN 14:2008/BTNMT only needs to be disinfected and put into the receiving source



b) The treated water does not meet QCVN 14:2008/BTNMT, there is still a lot of dirt (including microplastics) that needs pressure filtering before being put into the receiving source.

Figure 3.26. Proposed wastewater treatment technology diagram to reduce microplastics in the waste stream into the receiving source (Saigon - Dong Nai river)

The proposed technology diagram in Figure 3.26 is suitable for treating concentrated wastewater in industrial zones and domestic and urban wastewater containing many disease-causing microorganisms, bacteria and viruses, or high levels of nutrients such as BOD, Nitrogen, Phosphorus, persistent organic substances and microplastics.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The dissertation provides an overview of plastic waste, microplastics, their sources in river water and wastewater, as well as microplastic research methods based on NOAA guidelines and studies conducted both domestically and internationally. A water surface and wastewater sampling procedure tailored to the conditions of the Saigon–Dong Nai River and wastewater treatment plants (WWTPs) was developed. The microplastic analysis methods were carefully implemented to ensure accuracy and reliability.

A total of 432 surface water samples were collected from 18 locations in the Saigon–Dong Nai River basin during high tide, low tide, and in both rainy and dry seasons. The results indicated that all samples contained microplastics, with concentrations varying by tidal phase and season. Microplastics exhibited significant diversity in shape, quantity, and type, with higher variability observed during the rainy season and at high tide. Microplastic density correlated strongly with population density: in Tay Ninh (1,855 people/km^2), concentrations ranged from 440,363 to 481,020 microplastics/m^3, which was lower than in Ho Chi Minh City (4,375 people/km^2), where concentrations reached 729,502 microplastics/m^3. FTIR analysis identified over 60 types of polymers in river water.

Additionally, 312 wastewater samples were collected from six WWTPs in the Saigon–Dong Nai River basin across two seasons. Microplastics in wastewater were predominantly in fiber form, with densities ranging from 228,120×1,000 to 715,124×1,000 fibers/m^3. Microplastic concentrations were 3–5 times higher than in previous studies. While WWTPs are not specifically designed to remove microplastics, current treatment technologies achieve removal efficiencies of 85.4% – 93.7%, particularly for microplastics sized 1mm – 5mm. A total of 31 microplastic types were identified, with AMIDE (Nylon-PA) accounting for 36.9% and Ethylene for 34.08%.

Based on the study's findings, the dissertation proposes solutions to mitigate microplastic pollution in the Saigon–Dong Nai River. The feasibility of these solutions was assessed using the SWOT analysis method and a five-point Likert scale. The proposed solutions are scientifically grounded, highly feasible, and well-suited to real-world conditions.

Recommendation

The previous work needs to be expanded to further direct research on the observed size range of microplastics smaller than 1mm, in order to detect various representative types of microplastics in sample environments, particularly in water sources, and to secure funding for this research.

Up to this point, Vietnam has not established any technical regulations limiting the discharge of microplastics from treatment plants into water sources or water supplies for water treatment plants. Therefore, there is a necessity for research to develop specific standards and regulations for microplastics in the water environment, particularly water used for drinking and domestic purposes.

LIST OF PUBLISHED WORKS RELATED TO THE THESIS

1 Phu, H., **Han, H. T. N.**, Thao, N. L. N., Dong, D. V., & Han, T. G. (2021). *Research on the level of microplastic pollution in water and sediment of the Saigon – Dong Nai river.* Journal of Hydrometeorology, 731, 69-81.

2. Phu, H., **Han, H. T. N.**, & Thao, N. L. N. (2022). *Plastic waste, microplastics in the Saigon–Dong Nai river basin, the risk of impacts on the health of people.* VN J. Hydrometeorol, 736(1), 14-27.

3. Phu, H., **Han, H. T. N.**, Thao, N. L. N., & Ha, T. T. M. (2022). *Microplastics and solutions to remove microplastics in wastewater from wastewater treatment plants in the Saigon–Dong Nai river basin, Vietnam.* Vietnam J. Hydrometeorol, 12(13), 1-13.

4. Phu, H., **Han, H. T. N.**, & Thao, N. L. N. (2023, *August). Sources of microplastic pollution in the Saigon-Dong Nai rivers, potential risks affecting human health and recommendations for mitigation solutions*. In IOP Conference Series: Earth and Environmental Science (Vol. 1226, No. 1, p. 012017). IOP Publishing.

5. Phu, H., **Han, H. T. N.**, Thao, N. L. N., & Ha, T. T. M. (2022). *Overview of theoretical perspectives on methods of analyzing microsized plastics continental surface water.* Technology and Society Studies (STS) 2022 – HUTECH. Page 131 – 137. ISBN: 978-604-76-2568-0.

6. **Han, H. T. N.**, Phu, H., Hue, N. T., (2023). *Research to identify types of microplastics, their shapes, and trends over space and time, and to propose solutions to reduce microplastic pollution from plastic waste in the surface water of the Saigon – Dong Nai River, Vietnam.* The International Conference: Earth and Environmental Sciences, Mining for Digital Transformation, Green Development and Response to Global Change (Green EME 2023). Page 132 – 145. ISBN: 978-604-67-2826-9.

7. Phu, H., **Han, H. T. N.,** Hue, N. T., & Khang, V. H., (2023). *Applying algorithms based on the R language platform to study microplastics in continental surface water, Saigon River and Dong Nai River.* Journal of Hydrometeorology, 759, 46-63.

8. Phu, H., & **Han, H. T. N.**, (2024). *Evaluate plastic waste and microplastics in wastewater discharged from residential communities into the Saigon - Dong Nai rivers, propose treatment solutions to ensure sustainable development goals.* Journal of Hydrometeorology, 753, 37-49.

9. Phu, H., **Han, H. T. N.**, & Hue, N. T. (2024, August). *Developing a circular economy from plastic waste and identifying microplastics in domestic water supplies in Ho Chi Minh City and the Southeastern provinces.* In IOP Conference Series: Earth and Environmental Science (Vol. 1391, No. 1, p. 012011). IOP Publishing.

10. Phu, H., **Han, H. T. N.**, & Nu, T. N., (2024). Analytical methods used in microplastics identification: A review. VN J. Hydrometeorol 19, 12-22.

11. Phu, H., Khang, V. H., & **Han, H. T. N.**, (2024). *Applying information technology in analyzing and processing environmental data, evaluating the trend of changing the shape of microplastics in the water source of Saigon - Dong Nai River.* The Conference HUTECH 2024. Page 380-390, ISBN: 978-604-76-2945-9.

12. **Han, H. T. N.** (2024). *The Current Situation of Municipal Solid Waste and the Potential for Circular Economy Development from Plastic Waste in Ho Chi Minh City*. Environmental Journal, Issue III – 2024, pp. 3-11, ISSN: 2615-9597