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EVIDENCE OF MICROPLASTICS IN AGRICULTURAL WATER SYSTEMS OF NINH BINH PROVINCE, NORTHERN VIETNAM

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Abstract. Microplastics are regarded as an emerging threat to water and other environments. The increasing use of plastics in agricultural cultivation has led to higher risks and more dangerous pollution of agricultural water. However, microplastics in agricultural water in Vietnam have neither been studied nor documented in any publication. To provide initial scientific evidence of microplastics in agricultural water in the country, we conducted a case study in Kim Son district, Ninh Binh province. Water samples were randomly collected from 15 representative sites within the canal systems of the study area. Our study results indicated that the agricultural water in the study area was polluted by microplastics, which vary considerably in all size, shape, and color aspects. The average concentration of microplastics found in the examined water was 491 ± 259 particles/m³, with detected microplastic sizes ranging from 302 to 4,593 µm. Among these, microplastics sized between 300 and 1,000 µm were the most dominant, accounting for 61.8% of the total detected microplastics. In terms of shape, 94.5% of the detected microplastics were fibers, present at all 15 study sites, while only 5.5% were fragments, found at just seven sites. The microplastics were also highly diverse in color, with white being the most common and densely present in every analyzed water sample. The results of the present study provide the first scientific evidence of microplastic occurrence in agricultural water within the study area and can serve as a crucial basis for comprehensive research and effective management of plastic products in the future.

Keywords: agriculture, microplastics, pollution, Vietnam, water.

1. Introduction

Microplastics refer to small plastic fragments less than 5 mm in size [1]. A global review revealed that plastic production has rapidly increased over the past decades, from 2 million tons in 1950 to 348 million tons in 2017 and 368 million tons in 2019 [2]. Between 1950 and 2021, the total volume of plastic produced was approximately 8.3 billion tons, and it is estimated to double by 2040 [3]. Notably, the growth in plastic production has outpaced that of any other goods [2]. Due to their small size, lightweight nature, and ease of movement in the environment, microplastics can spread widely, posing health risks to both microorganisms and humans. They are found in almost all ecosystems, including soil, water, air, and biological organisms. Microplastics can originate from various sources, including daily activities, agricultural cultivation, industrial processes, and other sectors.

Agricultural cultivation and production have emerged as sources of microplastics entering water and sediment environments [4]. Plastic products are widely and extensively used in agriculture due to the versatility and diversity of plastic polymers, their beneficial physical properties, and their affordability for farmers and others. Many greenhouses are covered with plastic roofs to enhance crop productivity, while plastic films are also employed in livestock farming. Additionally, bags and packaging for pesticides and herbicides are made of plastic. It is estimated that the cultivation and livestock sectors use a large amount of plastic, approximately 10 million tons per year, followed by fisheries and aquatic aquaculture with 2.1 million tons annually. The volume of plastic used globally in agricultural cultivation for greenhouses, coatings, and composting films is projected to increase by 50%, from 6.1 million tons in 2018 to 9.5 million tons by 2030 [5]. While these plastic products benefit farmers and help conserve natural resources, they also pose critical risks. The use of plastic in agriculture has contributed to increasing microplastic pollution, which negatively impacts both human health and ecosystems.

In Vietnam, microplastics have been studied in several environments [6]-[16]. However, to our knowledge, all previous studies on microplastics in the country have focused solely on the surface waters of rivers, lakes, marine areas, and soil environments. As a result, microplastics in agricultural water have received little attention from both scientists and authorities. In fact, microplastics represent a growing threat as a form of pollution in agricultural ecosystems [17]. Notably, Vietnam is ranked among the top five rice-producing countries in the world and is home to two major river deltas: the Red River Delta and the Mekong Delta. To enhance our understanding of microplastics in agricultural water, we conducted a case study in the agricultural area of Kim Son District, Ninh Binh Province, within the Red River Delta. This district covers an area of 239.78 km² and is home to over 188,000 people as of 2023. Of these, 173,173 residents, accounting for approximately 92.1% of the district's population, are farmers [18]. To comprehensively develop the district's agricultural cultivation, livestock, and aquaculture, the "Agricultural Economic Development for the Period 2022–2025" project has been implemented. As a result, agricultural productivity has expressively increased, reaching up to 196 million VND per hectare, compared to the provincial average of 46 million VND per hectare [19]. While agricultural development has contributed to economic growth and improved incomes for local people, it has also heightened the risk of plastic waste entering the environment. Despite this growing concern, microplastic pollution in agricultural water in Kim Son district, and indeed in other localities across Vietnam, has received little scientific attention until now. Recognizing the risks posed by microplastics in the agricultural environment, we present scientific evidence of microplastic contamination in agricultural water downstream of the Day River. This case study offers a foundation for future considerations and management by scientists and authorities, from regional to international levels.

2. Content

2.1. Materials and methods

2.1.1. Study area

To assess the risks of microplastic pollution in agricultural water, we selected the canal systems throughout Kim Son district, Ninh Binh province, for random sample collection during this study. The study areas encompass canal systems in Binh Minh town and Con Thoi commune within the Kim Son district. Water samples were collected from 15 sites along the canals. Eight of these sites are located in Binh Minh town, while the remaining sites are in Con Thoi commune. The coordinates and surrounding habitat of the study sites are provided in Table 1.

Table 1. Study sites for agricultural water sampling in Kim Son district, Ninh Binh province, northern Vietnam

Study site ID (co-ordinates)	**Surrounding habitats**
KS1 (106°3’43’’N; 19°58’27”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS2 (106°3’42”N; 19°58’27”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS3 (106°3’44”N; 19°58’28”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS4 (106°3’46”N; 19°58’30”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS5 (106°3’47”N; 19°58’30”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS6 (106°3’51”N; 19°58’33”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS7 (106°3’58”N; 19°58’39”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS8 (106°4’48”N; 19°58’43”E)	Canal system supplying water for rice cultivation and duck farming in Binh Minh town.
KS9 (106°4’48”N; 19°58’57”E)	Canal system supplying water for rice cultivation in Con Thoi commune.
KS10 (106°4’48”N; 19°59’7”E)	Canal system supplying water for rice cultivation in Con Thoi commune.
KS11 (106°4’48”N; 19°59’11”E)	Canal system supplying water for rice cultivation in Con Thoi commune.

KS12 (106°4'48"N; 19°59'18"E)	Canal system supplying water for rice cultivation in Con Thoi commune.
KS13 (106°4'48"N; 19°59'17"E)	Canal system supplying water for rice cultivation in Con Thoi commune.
KS14 (106°4'48"N; 19°59'26"E)	Canal system supplying water for rice cultivation in Con Thoi commune.
KS15 (106°4'48"N; 19°59'34"E)	Canal system supplying water for rice cultivation in Con Thoi commune.

2.1.2. Sampling and analysis

A field trip for collecting agricultural water was carried out throughout the study sites in the rainy season in June 2024, after the rice harvest, when water levels in the canal system are typically moderate. At each study site, we collected 50 liters of agricultural water from the canal systems and filtered it through a specialized filter mesh with a pore size of 80 µm. The objects retained on the filter mesh after filtering each 50 liters of water were regarded as a sample, which was then transferred to a glass vial and stored at 4°C for analysis. All samples were analyzed following Strady et al. (2021) [20] with appropriate adjustments for practical application. Each sample was first filtered through a filter with a mesh size of 5mm x 5mm to separate the larger size portions. The filtered water with objects including microplastics smaller than 5000 µm in size was retained in a 500ml glass bottle, then analyzed using Sodium Dodecyl Sulfate (SDS, Merck®) at 50°C for 24 hours, biozyme SE (protease and amylase) and biozyme F (lipase) at 40°C for 48 hours and hydrogen peroxide (H_2O_2 30%, Merck®) at 40°C for 48 hours. After the analytical processes using the aforementioned chemicals, each sample was further filtered through a mesh filter with a size of 250 µm. Objects smaller than 250 µm were removed, while all objects larger than 250 µm were transferred to a clean glass beaker. A saturated NaCl solution was used for collecting microplastics. This process was repeated at least five times to ensure the recovery of all microplastics in each sample. Finally, the solution containing microplastics was filtered through GF/A filter paper (pore size 1.6 µm) using a glass filter. The filter paper containing the microplastics was placed in a sterile glass petri dish and examined under a Leica S9 microscope connected to a computer. The size, shape, and color of the microplastics were observed and recorded using LAS® software. In this study, following GESAMP's recommendations, we focused solely on microplastics with a minimum length of 300 µm and plastic fragments with a minimum area of 45,000 µm² or larger.

2.2. Results and discussion

2.2.1. Microplastic density in agricultural water at the study sites

Microplastics were detected at every study site within the canal systems supplying water to agricultural areas in Kim Son District, Ninh Binh Province (Figure 1).

Microplastic density varied widely among the study sites (Figure 1). Of the 15 sites, the highest microplastic concentration was observed at KS1, with 1,120 particles per cubic meter (m^3), while the lowest concentrations were recorded at KS8 and KS15, with 240 particles/m^3. The microplastic densities at the remaining sites ranged from 260 to 920 particles/m^3. The detected microplastic density at each study site depends on factors such as plastic erosion, waste flow, and the accumulation of microplastics over time and space. The KS1 site, located at the end of the agricultural canal system that drains into the Day River and subsequently flows to the sea through the Cua Day estuary, showed the highest concentration. Previous studies in other countries have highlighted similar sources of microplastics in agricultural water. Lwanga et al. (2023) [21] indicated that the use of compost and plastic mulch are major contributors to microplastic flow into soil and water environments. Additionally, soil amendments such as organic fertilizers, sewage sludge, and irrigation with wastewater often emit microplastics due to the large amounts of synthetic polymers in containers and other materials [22].

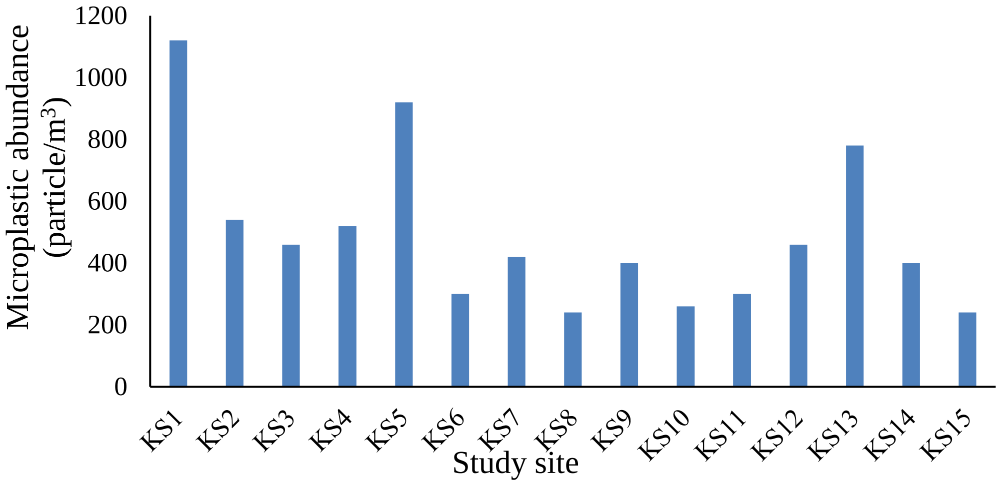

Figure 1. Microplastic abundance in agricultural water at each study site

With an average value of 491 ± 259 particles/m³, the microplastic density at the study sites was considerably lower than those reported in previous studies [5]. Wang et al. (2020) recorded microplastic densities in agricultural water from livestock farms ranging from 8,000 to 42,000 particles/m³ and in fish ponds ranging from 13,000 to 27,000 particles/m³, which are 16 and 85 times higher, respectively, than the levels found in the present study. However, the microplastic density in the downstream areas of the Day River is notably higher than previously reported in other rivers in Vietnam. Strady and Nguyen (2021) [23] recorded microplastic densities of 2.3 particles/m³ in the Red River, 2.7 particles/m³ in the Han River, 3.9 particles/m³ in the Dong Nai River, and 93.7 particles/m³ in the Nhue River. Another study reported an average microplastic density of 53.8 ± 140.7 particles/m³ in the Mekong River, with polyethylene (PE) being the most dominant type, comprising 67% of the total microplastics found [24].

2.2.2. Microplastic sizes in the studied agricultural water

The recorded microplastic sizes at the study sites ranged between 302 and 4,593 µm, with an average of 892 ± 198 µm (Figure 2). Among the observed and measured microplastics, 214 particles were classified as the smallest, with sizes between 300 and 1,000 µm, accounting for 61.5% of the total observed microplastic particles. At each study site, the proportion of these smallest particles ranged from 26.7% to 92.9% of the total number of microplastics. Additionally, 98 particles sized between 1,000 and 2,000 µm were observed, making up 28.2% of the total particle count. Larger particles, sized 2,000-3,000 µm, 3,000-4,000 µm, and 4,000-5,000 µm, were also found but only accounted for 6.6%, 2.5%, and 1.1% of the total microplastic numbers, respectively. The varying proportions of microplastic particles are likely due to the gradual fragmentation of larger plastic debris under environmental influences [25]. The portion of small particles recorded in this study is similar to those found in the Nhue and To Lich rivers, where Nguyen and Nguyen (2022) reported that the most dominant microplastics measured between 500 and 2,000 µm [11]. Several previous studies also reported the highest proportion of smaller microplastic particles in river waters in other countries [26], [27]. However, our findings differ clearly from those of Doan et al. (2021), where particles sized 300–1,000 µm made up only 78.5% of the total detected microplastics [28]. It is possible that Doan et al. (2021) studied the surface waters of the Day River, where microplastics accumulated, or the studied river sectors received higher microplastic densities from other canal systems. Further investigations are needed to fully understand the current state of microplastic pollution in the Day River.

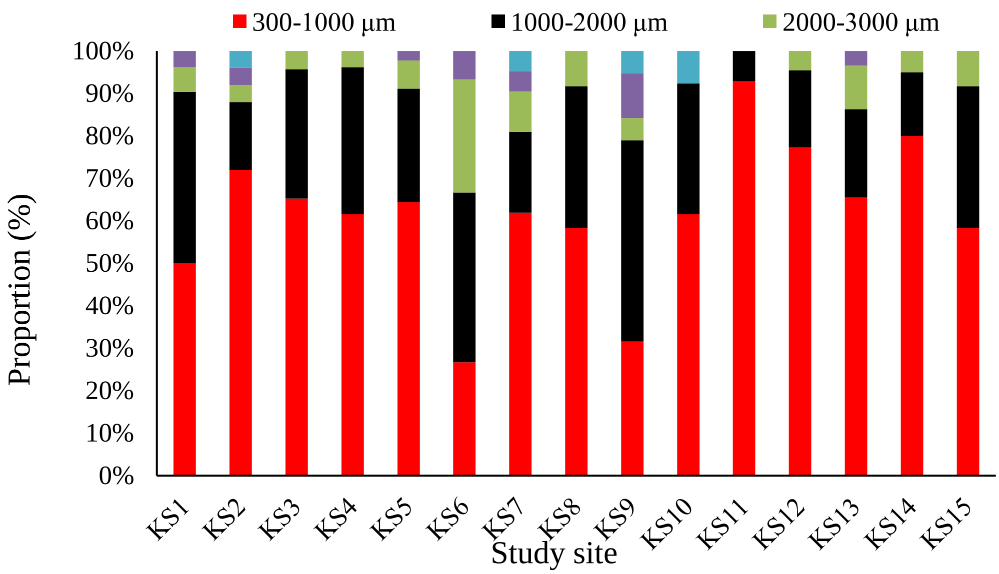

Figure 2. Proportions of microplastic sizes within each study site

2.2.3. Shape and color of the recorded microplastics in agricultural water

Regarding microplastic shapes, only fiber and flake microplastics were recorded at the study sites. Other shapes, such as round and film microplastics, which have been documented in other localities in previous studies, were not found in the study area in Kim Son district, Ninh Binh province (Figure 3).

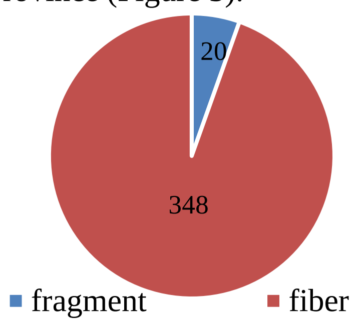

Figure 3. Shape of microplastics in agricultural water

Of the 368 detected microplastics, 348 were fibrous microplastics (also called fiber), accounting for the vast majority at 94.5%, while only 20 were flake microplastics (also called fragments), making up just 5.5%. Notably, fibrous microplastics were found at all 15 study sites, whereas flake microplastics were detected at only seven sites (Figure 4).

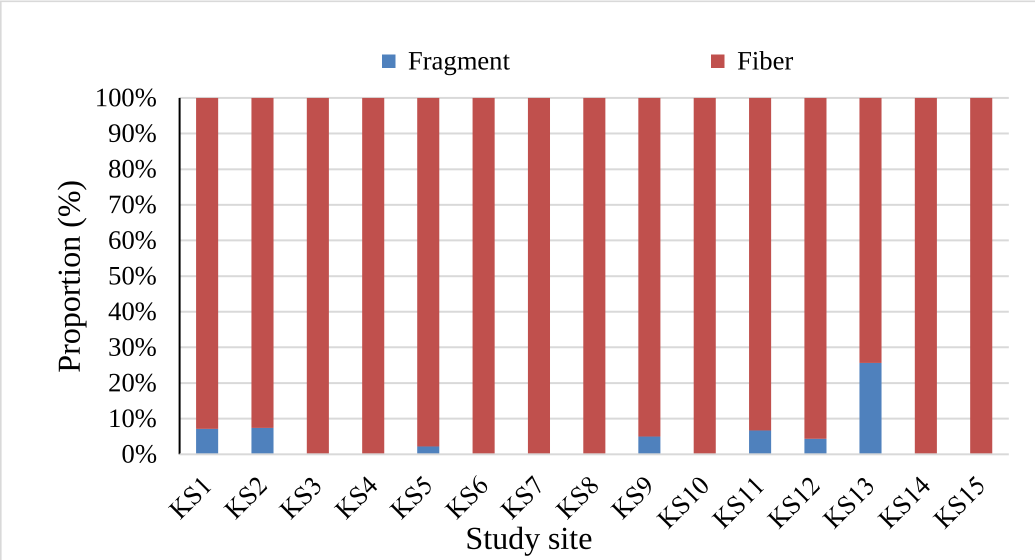

Figure 4. Proportions of microplastic shapes in agricultural water

Almost all previous studies on river water in Vietnam and other countries have indicated that fiber and flake microplastics are the most dominant types. Nguyen et al. (2023) studied microplastics at the Thuan An estuary in Thua Thien Hue province, Central Vietnam, and found that 80% of the total detected particles were fibers, while only 12.06% were flakes [10]. Notably, two other studies recorded fiber microplastics from the Mekong River and the surface waters of the Day River, with proportions of 85.00% and 92.00%, respectively [24], [28]. Some images of microplastics in agricultural wastewater from Kim Son district, Ninh Binh province are shown in Figure 5.

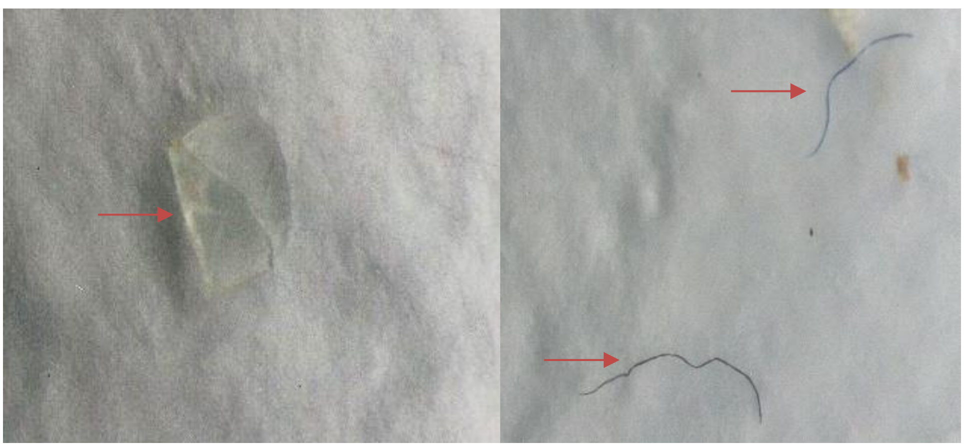

Figure 5. Selected images of fragment (left) and fibrous (right) microplastics in agricultural wastewater at the study sites

Regarding microplastic colors, all recorded particles were classified into seven color groups: red, blue, white, black, yellow, green, and purple. These colors have also been identified in several previous studies [26], [27], [29], [30]. Among the seven color groups at the study sites, white microplastics were the most predominant, comprising an average of 74.81 ± 11.29% of the total recorded microplastics.

To date, microplastics in agricultural water remain poorly studied in Vietnam and other countries. The results of this study differ remarkably from previous records of microplastics in agricultural water. For instance, Wang et al. (2020) examined agricultural water at several livestock farms and fish ponds, reporting color microplastics accounting for 60% and 73%, respectively, while white microplastics made up only 15% and 18% of the total [4]. However, the microplastic color proportions from this study are more comparable to those found in river water in China and Thailand [31]-[33].

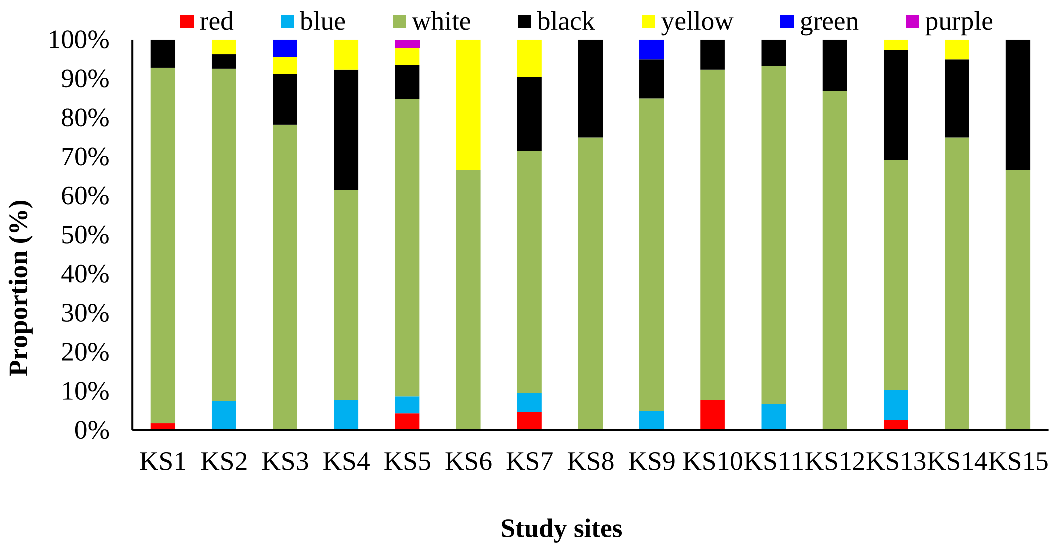

Figure 6. The proportion of color microplastics recorded in agricultural water

2.2.4. A comparison of recorded microplastics with those reported in the literature

Prior to this study, microplastics in agricultural water in Vietnam had neither been studied nor documented in any literature. Previous publications focused only on microplastics in soil environments and surface water from selected river sections (Table 2). In Vietnam, reported concentrations of microplastics in surface water varied widely, ranging from 2.3 particles/m³ to 863,005 particles/m³ (Table 2). Notably, the highest concentration was found in the downstream section of the Day River, which receives agricultural runoff from the study area. The microplastic concentration in the Day River's surface water was also clearly higher than those reported from rivers in other countries (Table 2). The findings of this study suggest that better control or management of microplastics in agricultural water within the study area could help reduce microplastic concentrations in the Day River and improve the broader water environment in Vietnam.

Table 2. A comparison of microplastic concentration, size, shape, and color in the water at the study area with those in published data

Location	Average concentration	Size	Shape	Color	Ref.
Agricultural water, Ninh Binh province, Vietnam	491 particles/m^3	300 - 1000 µm: 61.8% 1000 - 2000 µm: 27.5%	Fiber: 94.5%	White: 75.13 ± 11.29% Black: 15.09± 10.39%	The present study
Surface water, Day river, Vietnam	269,693-863,005 particles/m^3	300-1000 µm: 35.51-52.13% 1000-2000 µm: 30.58-42.93%	Fiber: 92%	Purple	[28]
To Lich river, Vietnam	2,522 particles/m^3	-	-	-	[23]
Nhue and Day river, Vietnam	706-754 particles/m^3	-	Fiber 85.66%	Blue + white: 80%	[11]
Nhue river, Vietnam	93.7 particles/m^3	-	-	-	[23]
Me Kong river, Vietnam	53.8 particles/m^3	-	Fiber: 85%	Blue: 50 % to 69 %, red: 24 % to 29 % White: 4 % to 29 %	[23]
Thuan An river, Vietnam	35 particles /m^3	-	Fiber: 80%	White: 44.0 % Blue: 39.7%	[10]
Dong Nai river, Vietnam	3.9 particles/m^3	-	-	-	[23]
Red river, Vietnam	2.3 particles/m^3	-	-	-	[23]
Surakarta, Indonesia	25,000-52,000 particles/m^3	300-1000 µm: 53.8 % 1000-2000 µm: 27.8 %	-	Blue: 45.1% Black 29.3 %	[26]

Location	Average concentration	Size	Shape	Color	Ref.
Malaysia	46,000-76,000 particles/m^3	-	-	-	[34]
Thailand	48 particles/m^3	-	-	White: 50.6%	[29]
Egypt	2,000-3,000 particles/m^3	2000 µm: 75%	Fiber: 79% Fragment: 15%; Others: 6%	Blue: 43% red: 16%	[27]
India	9,000 particles/m^3	-	Fiber: 44.2 %; Fragment :20.9 %; Others: 34.9 %	Black: 27.0 % Blue: 24.0 %	[30]
Changzhou, China	8,000-42,000 particles/m^3	-	-	Transparent: 60%. White: 15%	[4]
Changzhou, China	13,000-27,000 particles/m^3	-	-	Transparent: 73%. White: 18%	[4]
China	219,000 particles/m^3	-	Fiber; 81.52%	Black: 53.73% Transparent: 16.13%	[31]

3. Conclusions

The present study provides the first scientific evidence and characterization of microplastics in agricultural water in Vietnam. Our case study, conducted in specific agricultural areas of Kim Son district, Ninh Binh province, northern Vietnam, revealed a potential risk of microplastic pollution in the study areas. Microplastic densities in agricultural water at the study sites ranged from 240 to 1,120 particles/m^3, with an average of 491 ± 259 particles/m^3. Of the two recorded microplastic size groups, particles between 300 and 1,000 µm were the most dominant, accounting for 61.5% of the total microplastics. In terms of shape, fibers and fragments were identified, with fibers being overwhelmingly dominant at 94.5%. Among the seven recorded microplastic colors, white particles were the most prevalent, followed by black ones. Our study also highlighted the potential origins of microplastics in agricultural water at the study sites. Based on these initial findings, it is crucial to continue researching microplastics in agricultural water, expanding the scope and study areas for a comprehensive assessment of microplastic pollution at national and international scales.

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REFERENCES

[1] Andrady AL, (2011). Microplastics in the Marine Environment. *Marine Pollution Bulletin*, .62, 1596-1605. doi.org/10.1016/j.marpolbul.2011.05.030.

[2] OECD, (2022). *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*.

[3] Wen Z, Xie Y, Chen M & Dinga CD, (2021). China's plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nature Communications*, 12(1), 425.

[4] Wang F, Wang B, Duan L, Zhang Y, Zhou Y, Sui Q, Xu D, Han Q & Yu G, (2020). Occurrence and distribution of microplastics in domestic, industrial, agricultural and aquacultural wastewater sources: A case study in Changzhou, China. *Water Research* 182, 115956. doi.org/10.1016/j.watres.2020.115956.

[5] FAO, (2021). *Assessment of Agricultural Plastics and Their Sustainability: A Call for Action*, Rome, doi.org/10.4060/cb7856en.

[6] Dinh HN, Duong TN & Le VNam, 2021. Assessment of current and characteristics microplastic in the marine environment of Cat Ba Island (Hai Phong, Vietnam). *Journal of Environment*, Thematic, (4- December 2021), 67-70 (in Vietnamese).

[7] Dinh HN, Duong TN, Cao TTN, Le TPQ, Doan TO, Nguyen TK & Duong TT, (2023). Comparison protocols for extraction of microplastics in water samples. *Vietnam Journal of Marine Science and Technology*, 23(1), 103-112.

[8] Le ND, Phung TXB, Hoang TTH, Duong TT, Nguyen TAH, Nguyen TML & Le TPQ, (2022). Preliminary observation of microplastic contamination in some spice-salt samples purchased in Hanoi city. *Vietnam Journal of Food Control*, 5(3), 207-216 (in Vietnamese).

[9] Nguyen HNY, Phan TTL, Vo DHL, Vo VM, Le TM, Trinh DM & Tran NQA, (2022). Microplastics pollution in surface water of urban lakes in Danang. Vietnam, *The University of Danang - Journal of Science and Technology*, 20(8), 88-92 (in Vietnamese).

[10] Nguyen HNY, Truong TNH, Phan TTL, Vo VM, Le TM, Trinh DM & Tran NQA, (2023). Distribution of microplastics in the surface water and sediment of Thuan An estuary, Thua Thien Hue province. *The University of Danang - Journal of Science and Technology*, 21(3), 97-103 (in Vietnamese).

[11] Nguyen HT & Nguyen TH, (2022). Research on the state of the microplastic pollution in the Nhue and Day river basins. *Journal of Environment*, Thematic, (4-December 2022), 39-44 (in Vietnamese).

[12] Pham MH, Nguyen MH, Dao HT, Le HL, Nguyen DC & Vo HC, (2022). Microplastic Production from Plastic Recycling Village in Van Lam, Hung Yen Province. *VNU Journal of Science: Earth and Environmental Sciences*, 38(2), 94-102 (in Vietnamese).

[13] Pham NHV, Vu NM, Duong TN, Nguyen VN, Do TQ, Nguyen TH & Bui BT, (2022). Researching and determining the distribution of microplastics in coastal sediments from the Ba Lat estuary to the Day estuary. *Journal of Environment*, Thematic, (4-December 2022), 45-50 (in Vietnamese).

[14] Phuong NN, Pham QT, Ngo TXT, Nguyen TMD, Duong TT, Le TPQ, Le ND, Phuong NA, Duong TN & Le QT, (2022). Initial survey on microplastic waste in coastal water in Nam Dinh. *Vietnam Journal of Marine Science and Technology*, 22(2), 209-216.

[15] Truong TNS, Tran QV, Le TMT, Thuong QT, Strady E & Kieu LTC, (2019). Extraction of the anthropogenic fibers in the atmospheric fallout in Ho Chi Minh city. *Ho Chi Minh City University of Education Journal of Science*, 16(3), 17-24.

[16] Tran NQA, Le TM, Nguyen HNY & Nguyen QT, Mau Trinh-Dang, (2024). Microplastics in the surface water of urban lakes in central Vietnam: Pollution level, characteristics, and ecological risk assessment. *Case Studies in Chemical and Environmental Engineering*, 9, 100622.

[17] Quilliam RS, Pow CJ, Shilla DJ, Mwesiga JJ, Shilla DA & Woodford L, (2023). Microplastics in agriculture - a potentially novel mechanism for the delivery of human pathogens onto crops. *Frontiers in Plant Science*, 14(10), 1-7.

[18] Ninh Binh Statistics Office, (2024). *Ninh Bình Statistical Yearbook 2023*. Statistical Publishing House (in Vietnamese).

[19] People’s Committee of Kim Sơn district, (2022). Report No. 787/BC-*UBND dated December 7, 2022, Report on results of implementing socio-economic development tasks in 2022, goals, tasks, and solutions for socio-economic development in 2023* (in Vietnamese).

[20] Strady E, Dang TH, Dao TD, Dinh HN, Do TTD, Duong TN, Duong TT, Hoang DA, Le CTK, Le TPQ, Mai H, Trinh DM, Nguyen QH, Nguyen QAT, Tran QV, Truong TNS, Chu VH & Vo VC, (2021). Baseline assessment of microplastic concentrations in marine and freshwater environments of a developing Southeast Asian country, Vietnam. *Marine Pollution Bulletin*, 162, 111870.

[21] Lwanga EH, Roshum I, Munhoz DR, Meng K, Rezaei M, Goossens D, Bijsterbosch J, Alexandre N, Oosterwijk J, Krol M, Peters P, Geissen V & Ritsema C, (2023). Microplastic appraisal of soil, water, ditch sediment, and airborne dust: The case of agricultural systems. *Environmental Pollution*, 316, 120513. doi.org/10.1016/j.envpol.2022.120513.

[22] Bläsing M & Amelung W, (2018). Plastics in Soil: Analytical Methods and Possible Sources. *Science of the Total Environment*, 612, 422-435. doi.org/10.1016/j.scitotenv.2017.08.086.

[23] Strady E & Nguyen MT, (2021). Evaluation of microplastics in the water environment in Vietnam. *Journal of Environment*, (9), 25-27 (in Vietnamese).

[24] Le TCK, Thuong QT, Truong TNS, Le MTM, Tran QV & Strady E, (2023). Baseline concentration of microplastics in surface water and sediment of the northern branches of the Mekong River Delta, Vietnam. *Marine Pollution Bulletin*, 187, 114605.

[25] Zhou Q, Zhang H, Fu C, Zhou Y, Dai Z, Li Y, Tu C & Luo Y, (2018). The Distribution and Morphology of Microplastics in Coastal Soils Adjacent to the Bohai Sea and the Yellow Sea, *Geoderma*, 322, 201-208. https://doi.org/10.1016/j.geoderma.2018.02.015.

[26] Ismanto A, Hadibarata T, Sugianto DN, Zainuri M, Kristanti RA, Wisha UJ, Hernawan U, Anindita MA, Gonsilou AP, Elshikh MS, Amal M, Mohaimeed A & Abbasi AM, (2023). First evidence of microplastics in the water and sediment of Surakarta city river basin, Indonesia. *Marine Pollution Bulletin*, 196, 115677, doi.org/10.1016/j.marpolbul.2023.115677.

[27] Khedre AM, Ramadan SA, Ashry A & Alaraby M, (2024). Abundance and risk assessment of microplastics in water, sediment, and aquatic insects of the Nile River, *Chemosphere*, 353, 141557. doi.org/10.1016/j.chemosphere.2024.141557.

[28] Doan TO, Duong TT, Nguyen TNH, Hoang TQ, Le TPQ, Duong HP, Le PT & Bui HT, (2021). Preliminary results on microplastics in surface water from the downstream of the Day River. *Vietnam Journal of Earth Sciences*, 43(4), doi.org/10.15625/2615-9783/16504.

[29] Ta AT & Babel S, (2020). MPs pollution with heavy metals in the aquaculture zone of the Chao Phraya River Estuary. Thailand. *Marine Pollution Bulletin*, 161, 111747, doi.org/10.1016/j.marpolbul.2020.111747.

[30] Patidar K, Ambade B, Younis AM & Alluhayb AH, (2024). Characteristics, fate, and sources of microplastics contaminant in surface water and sediments of river water, *Physics and Chemistry of the Earth*, 134, 103596, doi.org/10.1016/j.pce.2024.103596.

[31] Bao R, Wang Z, Qi H, Mehmood T, Cai M, Zhang Y, Yang R, Peng L & Liu P, (2022). Occurrence and distribution of microplastics in a wastewater treatment plant in a tropical region of China. *Journal of Cleaner Production*, 349, 131454, doi.org/10.1016/j.jclepro.2022.131454.

[32] Lin L, Zuo LZ, Peng JP, Cai LQ, Fok L, Yan Y, Li HX & Xu XR, (2018). Occurrence and distribution of microplastics in an urban river: a case study in the Pearl River along Guangzhou city, China. *Science of the Total Environment*, 644, 375-381. https://doi.org/10.1016/j.scitotenv.2018.06.327.

[33] Chinfak N, Sompongchaiyakul P, Charoenpong C, Shi H, Yeemin T & Zhang J, (2021). Abundance, composition, and fate of microplastics in water, sediment, and shellfish in the Tapi-Phumduang River system and Bandon Bay, Thailand. *Science of The Total Environment*, 781, 1146700, doi.org/10.1016/j.scitotenv.2021.146700.

[34] Karing DJ, Anggiani M, Cao LTT. El-shaammari M, (2023). Occurrence of microplastics in Kemena River and Niah River of Sarawak, Malaysia. *Tropical Environment, Biology, and Technology*, 1(1), 1-13. doi.org/10.53623/tebt.v1i1.220.