Membrane and Water Treatment, *Vol. 14, No. 4 (2023) 147-153*
https://doi.org/10.12989/mwt.2023.14.4.147

Characteristics of micro-plastics in stormwater sediment basin: Case study of J wetland

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(Received August 14, 2023, Revised September 15, 2023, Accepted September 20, 2023)

Abstract. Urbanization has been causing such new pollutants as micro-plastic, thus the environmental impact of new pollutants on ecosystem is rapidly increasing. When it comes to micro-plastic, a representative artificial trace pollutant, its risk has been increased at a much faster rate, however the depth study associated with stormwater sediment and wetland was relatively rare. In this research, soil samples from storm water sediment were analyzed for distribution characteristics of micro-plastics in the J wetland (registered as Ramsar wetland, May 2021 and a representative environmental site in South Korea). Analyzed soil samples found approximately 201 ± 93 particle/kg (based on unit weight, Total micro plastic particles / Total Sample weight) micro-plastics in the samples. When considering the total quantitative numbers in stormwater sediment in the entire area of the J wetland, over 15,000 micro-plastics were estimated to be contaminating such area. In addition, in terms of qualitative numbers, micro-plastics were contaminating the J wetland with 94.7 % ratio of styrofoam type (43.9%) and polyethylene type (50.8%). These research results can be used as base data sets for controlling micro-plastics in the J wetland.
Keywords: micro-plastic; sediment; stormwater; wetland

1. Introduction

The J wetland is located at the Han River Estuary, South Korea and was registered as Ramsar site, May 2021. Except for some people engaged in agriculture or fishing in J wetlands, the site has been quite limited to the public access. In addition, the J wetland stretches out 7.6 km along the Han River Estuary, including various environmental conditions such as tidal forest, marsh, estuarine tidal flat, and freshwater tidal forest. Under these conditions, 122 species of birds (23 endangered species, 18 natural monuments, and 2 marine protected species), 390 species of plants, 11 mammals, and 65 species of insects were reportedly existing in valuable ecological system. In geographical characteristics of the J wetland, it is adjacent to J road, known as one of the areas with the highest traffic volume in Korea, and large-scale residential areas, while being exposed to the inflow of man-made pollutants. Currently, point pollution sources occurring in areas near the J wetland have been under control. However inflow of non-point pollutants from J road and nearby industrial complexes has not been under control without appropriate management program. In particular, pollutants including heavy metals and micro-plastics generated by vehicle traffic in J road can directly be introduced into the J wetland, which can be a potential threat to the ecosystem in J wetlands, so a research and protection measures must be urgently required. Research related to J wetlands focusing on ecosystems and geographical characteristics, spatial distribution of micro-plastics in wetlands, and relative data on pollution should be enlightened. In other words, as the J wetland was designated the Ramsar wetland, a database of pollutants can be fundamental to ecologically managing the J wetland system.

Plastic refers to as polymer material and a mixture thereof that can be molded by heat or pressure, and is used in various fields of human life. The plastics are very useful, providing convenience for human life (Carr *et al.* 2016, Jeong *et al.* 2018, Mintentig *et al.* 2017), but it requires a long time to decompose itself in the natural world after being disposed of, causing long-term environmental problems in the natural ecosystem if not processed (Choi *et al.* 2019, Hong *et al.* 2013, Jeon *et al.* 2019, Kim *et al.* 2019, 2022a, Kwak *et al.* 2020, Salim *et al.* 2019). Therefore, plenty of studies on micro-plastics have been conducted in the field of ecological environment. Although some research is underway on marine and fresh water pollution caused by micro-plastics, but not many studies have been conducted on micro-plastics on the soil surface near the wetland (Kim *et al*. 2020, SERI, 2014, 2016, Mason *et al*. 2016). This goes to say that micro-plastic analysis in soil is more difficult than the analysis in water, and that research on the analytical method has newly begun (Chae *et al.* 2014, Murphy *et al.* 2016, NIER 2016, Ziajahromi *et al.* 2017). In addition, micro-plastics are known to be a representative substance with a high risk of biomagnification, thus destroying the ecological hierarchy (Kim *et al.* 2022b, Lee *et al.* 2023, Li *et al.* 2020, Talyitie *et al.* 2017).

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http://www.techno-press.org/?journal=mwt&subpage=7 ISSN: 2005-8624 (Print), 2092-7037 (Online)

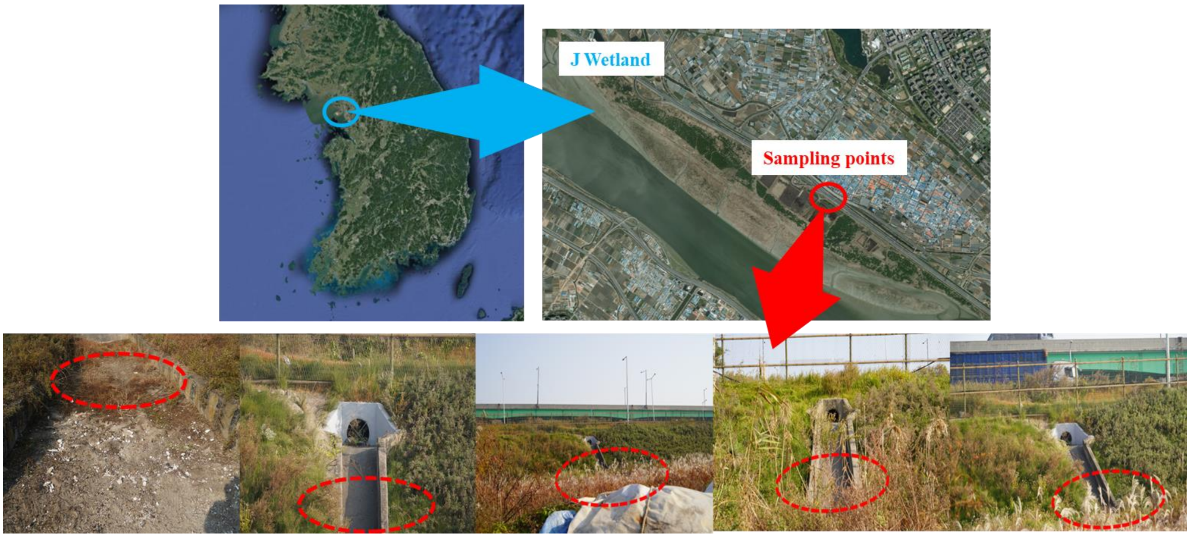


Fig. 1 Location of the sampling points in J wetland, Korea (Google map)

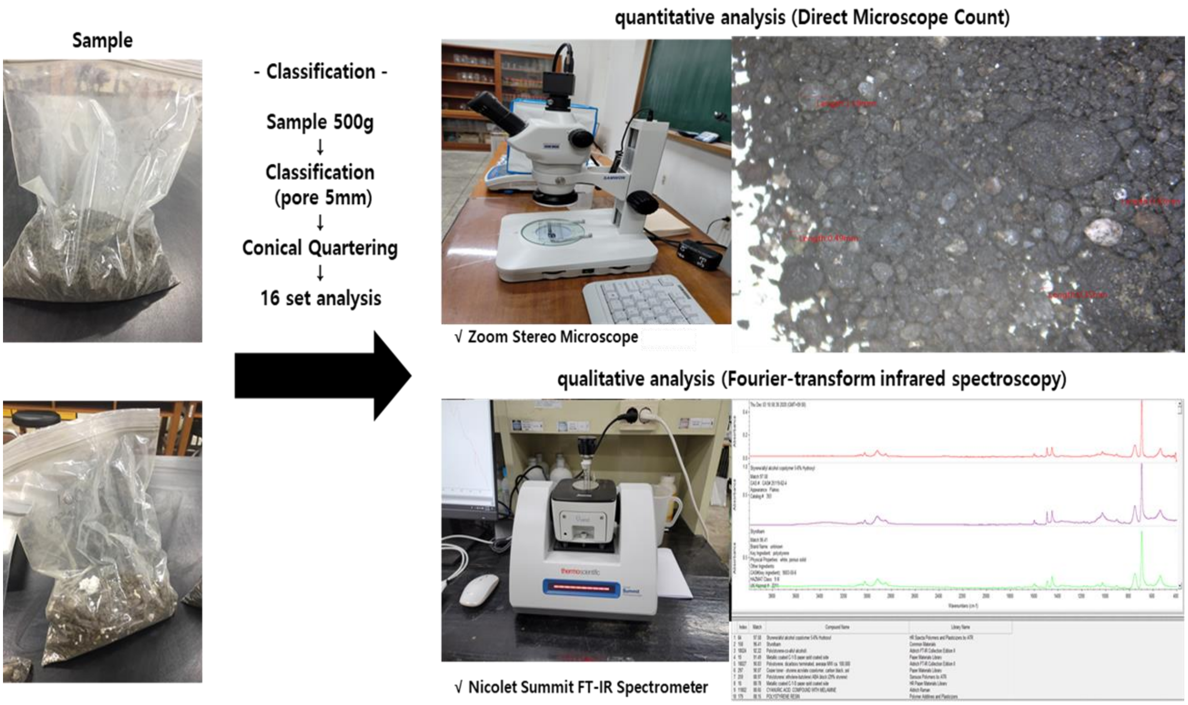


Fig. 2 Analysis procedure of micro-plastics used in this study

In this study, the objectives were geared to collect the samples and analyze them with spatial distribution of micro-plastics, which will make a data base from quantitative and qualitative results. Such fundamental data will be useful to eventually managing and mapping out on the wetland program in the future.

2. Materials and methods

2.1 Monitored site

There are five monitoring points, and sediments in stormwater line, connected to J road. The reason why the sediment in the stormwater was selected as one of monitoring target points was to understand the possible impact from outside. In addition, when determining the monitoring target point, it was quite difficult to collect samples from the entire area with limitations such as the period of study, and the limited time of access to wetlands, so an area with high vehicle traffic was selected in the first place. Fig. 1 shows the pictures of monitoring points in this study.

2.2 Analysis process of micro-plastic

According to advanced researches, many methods the were proposed for analyzing micro-plastics. The sample yet a standardized method has not been established (Oh and Lee 2021). Therefore, in this research, a micro-plastic

Table 1 Summary of micro-plastic particles in monitoring result

Parameters	Point 1	Point 2	Point 3	Point 4	Point 5	Total
Sample 1	114	52	40	149	126	481
Sample 2	170	57	27	112	157	523
Average (STD)	142 ± 40	55 ± 4	34 ± 26	131 ± 26	142 ± 22	502 ±22

*Note: All units are particle count

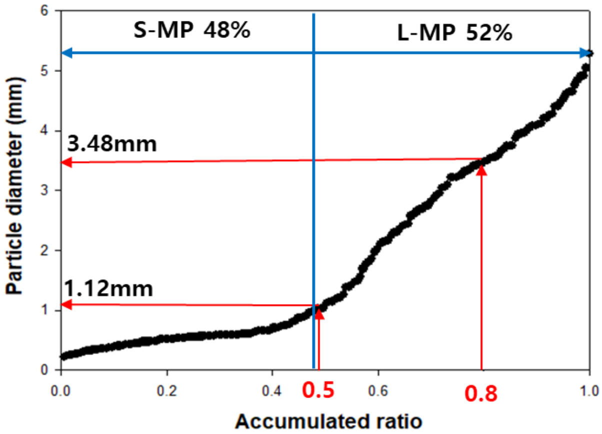


Fig. 3 Micro-plastic particle diameter distribution graph in samples

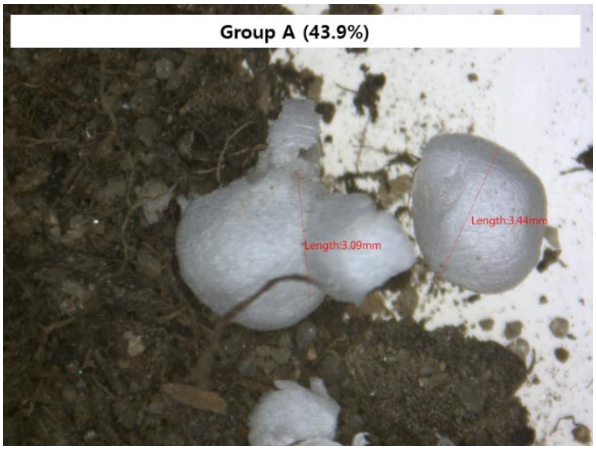
analysis was established in three steps: Sample – Pre-treatment – Analysis, based on existing literature review (Kim and Gil 2022c, Oh and Lee 2021). Fig. 2 shows a summary of analysis procedure of micro-plastic used in this research.

2.2.1 Sample

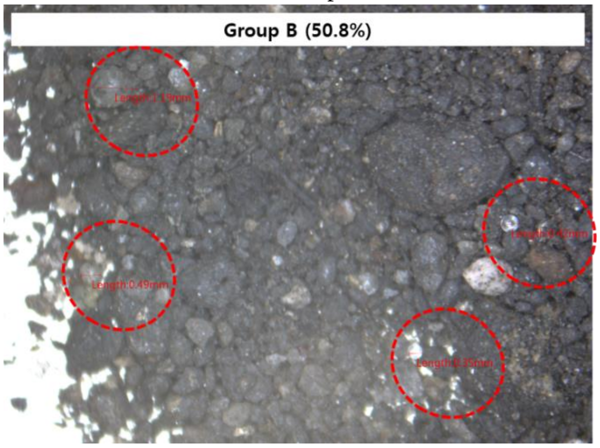
When collecting samples from the ocean, it should be carried out by shifting the samples, using a net or a pump (Kim and Gil 2022c, Riaz *et al.* 2022). At this time, the pores of the sieve can be determined by the researcher, according to the size of the micro-plastics to be analyzed (usually determined in the range of 25 to 500 μm). However, since this research will take a sample of land, it was determined to collect a certain amount of soil on the surface at the designated sample collection points. Two samples were collected at a total of five pipeline collection points. Sample collection was conducted at intervals of 30 d.

2.2.2 Pre-treatment

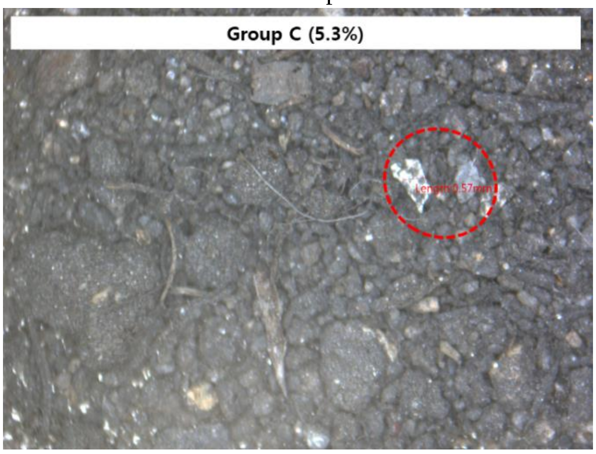
For the analysis of the collected samples, 500 g was classified through a conical quadrant. Each sample was filtered through a 5 mm size sieve (No. 4) and 75 μm size sieve (No. 200) made by Chung gye sang gong sa, Seoul, Korea to remove contaminants that did not meet the definition of micro-plastics. After this process, the samples were transferred to a square tray then divided into 16 equal parts. Prepare was produced with a sample of a degree that can be observed with an optical microscope in each divided section.



Group A



Group B



Group C

Fig. 4 Sample photos of micro-plastic particles: (a) Group A, (b) Group B, and (c) Group C

2.2.3 Sample analysis

Quantitative analysis of sample was conducted on the after pretreatment step, using an optical microscope. In this case, the sample used for quantitative analysis is 1/815 times the sample classified, and, the number of micro-plastic particles in the J wetland can be estimated. In the analysis process, the sample was loaded under a microscope (JSZ-7XB, Human instrument company), and the number of artificial substances was recorded and classified. Qualitative analysis of sample was performed using Fourier-transform infrared (FTIR) spectroscopy. The FTIR analyzer used Nicolet™ Summit™ FTIR Spectrometer by ThermoFisher Scientific. Qualitative analysis was performed on particles classified in the quantitative analysis procedure to identify their properties.

3. Results and discussion

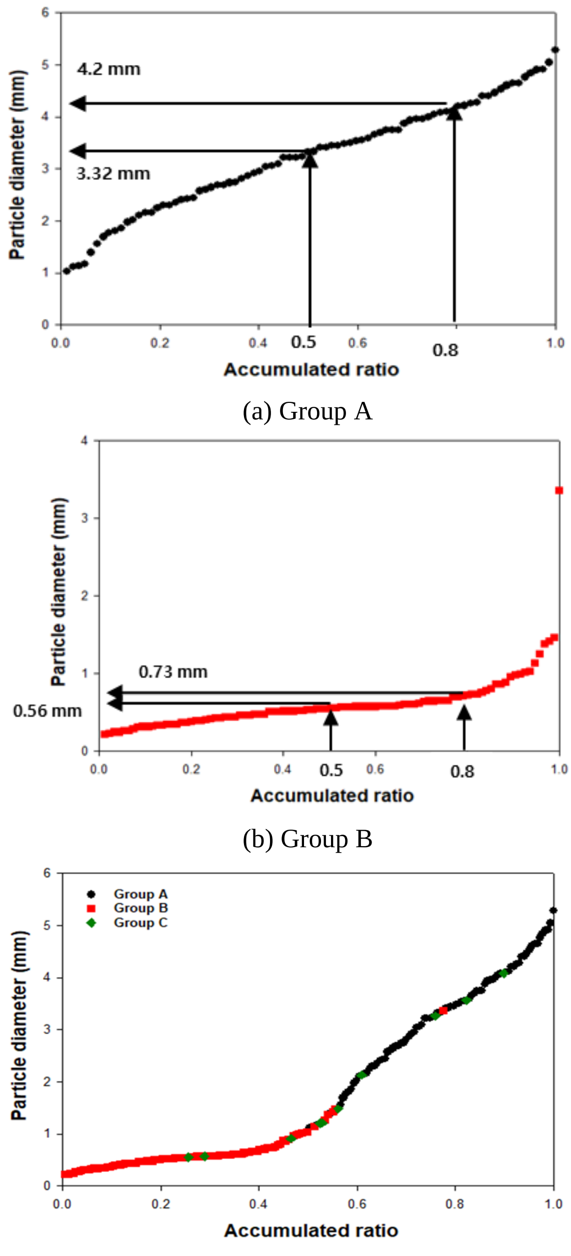
3.1 Quantitative analysis of micro-plastic

Table 1 summarizes the number of micro-plastics in soil samples at five monitoring points. In the case of the 1st monitoring (Sample 1), each monitoring point micro-plastics ranged from 40 to 149, and the maximum value of 149 micro-plastics was detected at Point 4. A total of 481 micro-plastics/monitoring were detected in the primary monitoring samples. When converting this into the detection amount as equivalent as the unit weight and area, it could be analyzed as 192 particle/kg and 385 particle/m^2. In the case of the 2nd monitoring (Sample 2), a total number of 523 micro-plastics were detected. The number of micro-plastics for each monitoring point was 27 to 170, and the maximum value of 170 was detected at point 1. The detection amounts in terms of the unit weight and area were 209 particle/kg and 418 particle/m^2.

As a result of the total monitoring activity, a total number of 1,004 micro-plastics were detected in a sample of 5 kg and an area of 2.5 m^2. When converted into a unit weight and an area, it was 201 particle/kg (based on unit weight, Total micro plastic particles / Total Sample weight) and 402 particle/m^2 (based on unit area, Total micro plastic particles / Total sampling point area) and it can be viewed that a large number of micro-plastics exist in the soil in the stormwater sediment of the J wetland. When it comes to estimating the total number of micro-plastics (limited to soil in the stormwater sediment) in the J wetland, it was estimated that approximately 15,207 micro-plastics (76 sediment of the J wetland) were existing.

3.2 Physical characteristics of micro-plastic in stormwater sediment

Fig. 3 is a particle diameter distribution graph analyzed, based on the size measured through an optical microscope for micro-plastics in a sample (1,004 in total). In the sample, the ratio of small micro-plastics (S-MP, diameter less than 1 mm) was 48 %, and the ratio of large micro-plastics (L-MP, diameter 1 mm to 5 mm) was 52 %, indicating no significant difference between the two groups. The detection range of micro-plastic particles was 0.22 mm to 5.28 mm (based on the diameter), and the 50 % (medium) particle size was 1.12 mm and the 80 % particle size was 3.48 mm. The detected micro-plastics can be clearly classified into three groups according to their shape, and it can be confirmed through Fig. 4. Group A is a styrofoam type micro-plastics, Group B is a circular micro-plastics with artificial processing type, and Group C is a micro-plastics that do not belong to Group A or Group B.



(a) Group A

(b) Group B

(c) Total micro-plastic with grouping

Fig. 5 Micro-plastic particle diameter distribution graph according to group analysis: (a) Group A, (b) Group B, and (c) Total micro-plastic with grouping

Group A and B were analyzed as dominant groups, accounting for 94.7 % of the total micro-plastics (Group A 43.9 % and Group B 50.8 %). As a result of analyzing the particle diameter distribution graph of micro-plastic particles for dominant groups (Group A and Group B), a singularity was observed. In Fig. 5(a), Group A particle size, the detection range of micro-plastic particles was 1.03 mm to 5.28 mm (based on the longitudinal diameter), and the 50 % (medium) particle size was 3.32 mm and 80 % particle size was 4.2 mm, consisting of 100 % L-MP. In the case of Group B (Fig. 5 (b)), the detection range was 0.22 mm to 3.36 mm (based on the longitudinal diameter), and the 50 % (medium) particle size was 0.56 mm and the 80%

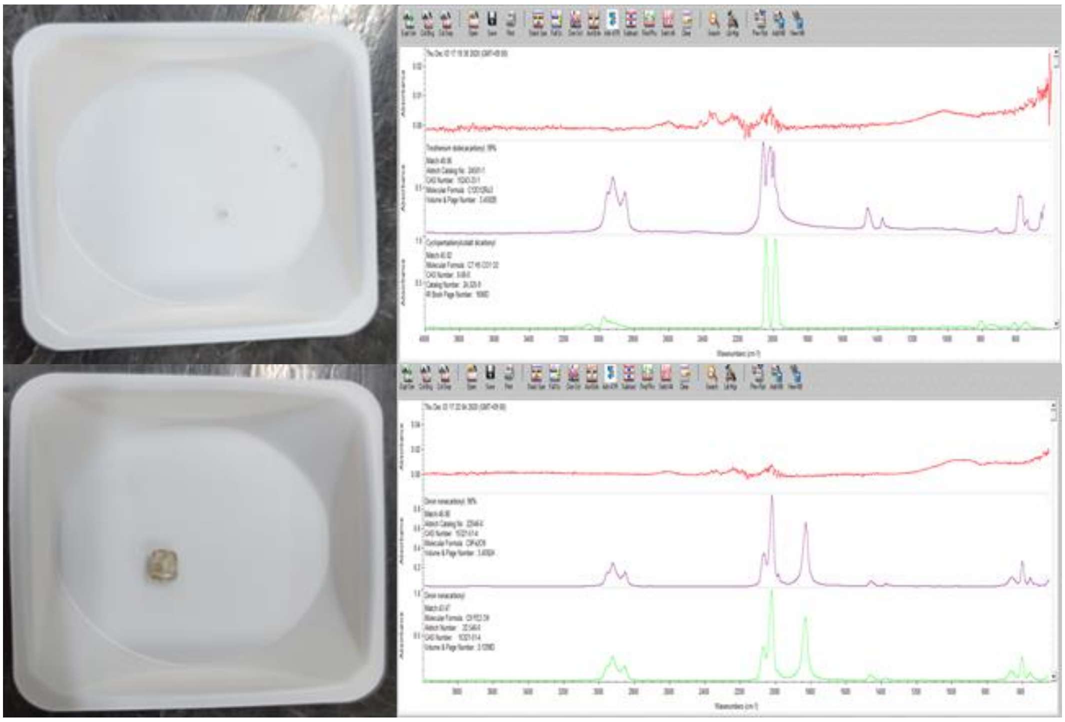


Fig. 6 Sample qualitative analysis results of micro-plastic based on FT-IR

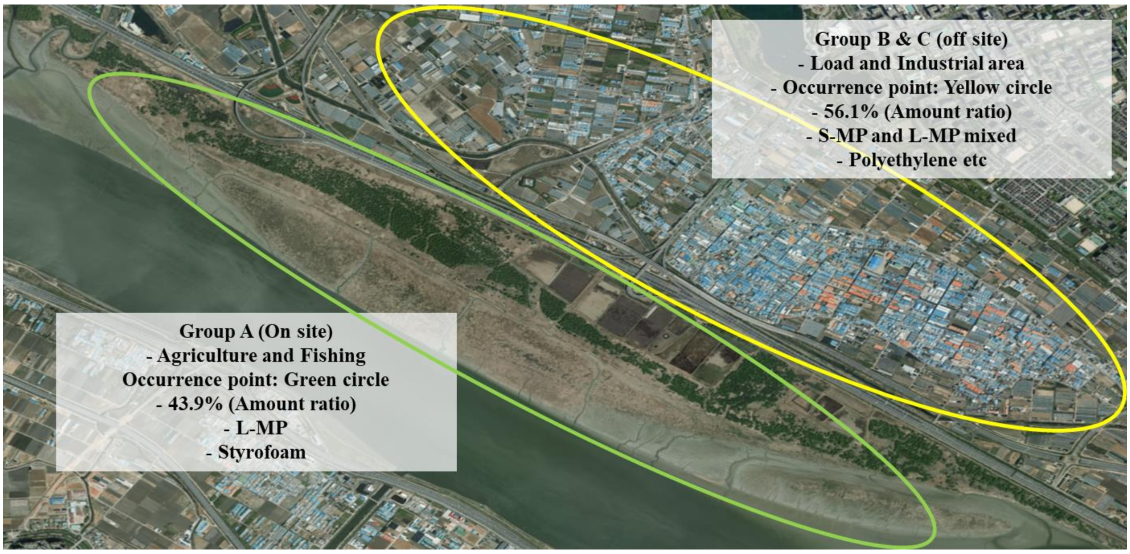


Fig. 7 Analysis results of micro-plastics in the J wetland stormwater line sediment

particle size was 0.73 mm, showing that 92% of S-MP. Such characteristics can also be confirmed through the entire micro-plastic particle diameter distribution classified by group in Fig. 5 (c). The reason for the evident characteristics of micro-plastics was due to the fact that the sources of micro-plastics were affected by the geographical characteristics of external roads, industrial complexes, agricultural and fishing activities.

3.3 Qualitative analysis and micro-plastic source

Fig. 6 shows FTIR analysis results of micro-plastics in the samples. The FTIR results of sample were analyzed with database from ThermoFisher Scientific. The red, purple and green lines in the Fig. 6 represent absorbance according to wavelength. The red line is the analysis result of the sample, and the purple and green lines are the analysis results of substances with high similarity to the samples in the database. The qualitative analysis results of micro-plastics showed differences in Group A, B, and C. Group A appeared as Styrofoam, as confirmed through an optical microscope, and Group B was as Polyethylene. However, Group C was found to contain a mixture of substances probably used in manufacturing industries such as Iron pentacarbonyl, Diiron nanocarbonyl, Triruthenium dodecacarbonyl, Penylethynyl, Cobalt thiocyanate, etc. In addition, the results of estimating pollutant source for each group through the quantitative analysis results and the geographical analysis results of J wetlands are summarized in Fig. 7. Group A was due to on-site (internally generated) pollutants from agricultural and fishing activities inside the J wetland. Groups B and C were caused by off-site (externally generated) pollutants that might occur in J road and nearby industrial areas. Therefore, micro-plastics in the J wetland were caused by internal pollutants (43.9 %) and external pollutants (56.1 %).

4. Conclusion

1. Micro-plastics in the monitored soil of the stormwater line sediment in the J wetland, analyzed as 201 particle/kg and 402 particle/m^2. It was estimated that approximately 15,207 micro-plastics were distributed in the J wetland sediment basin (In case of stormwater line sediment).

2. It was confirmed that there were two dominant groups of micro-plastics in the J wetland. Group A was found to be styrofoam type L-MP 43.9 % (quantitative ratio) and Group B was polyethylene type S-MP 50.8 % (quantitative ratio), accounting for 94.7 % of total micro-plastics.

3. As a result of analyzing the micro-plastics source in the J wetland, Group A was an on-site (agriculture and fishing) and Group B and C were an off-site (manufacturing industries). There were two pollutants of micro-plastic with different occurrence characteristics, it is essential to establish a suitable management method to characterize the micro-plastics.

4. The micro-plastics investigated in this research were analyzed in sampling points of J wetland (5 stormwater sediment basin), so there is a limit to generalization and application. In addition, it is difficult to clearly discuss the risk of micro-plastic because not enough research has been conducted on micro-plastic in wetlands. However, the results of the detection of micro-plastics in Ramsar wetlands with high ecological value suggest that management of micro-plastics in wetlands is necessary in the future. In the future, additional research is needed to conduct detailed research on the current status of micro-plastics in areas with high ecological value.

Acknowledgments

This study was supported by the Research Program funded by the SeoulTech (Seoul National University of Science and Technology).

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