Membrane and Water Treatment, *Vol. 15, No. 3 (2024) 99-106*
https://doi.org/10.12989/mwt.2024.15.3.099

Water quality management strategy based on organic matter characteristics of streams and lakes in the Namhan River Watershed

Hyeonjong Youn, Chaewon Kang and Kyungik Gil*

Department of Civil Engineering, Seoul National University of Science and Technology, 232, Gongneung-ro, Nowon-gu, Seoul, South Korea, 01811

(Received May 8, 2024, Revised July 16, 2024, Accepted July 24, 2024)

Abstract. This study developed an efficient management plan to improve the water quality by analyzing fluctuations in the ratio and amount of various organic substances in streams considering watershed characteristics and rainfall patterns. Monitoring was conducted on three streams and one lake over seven sessions during wet and dry seasons. Water quality indicators including total organic (TOC), refractory dissolved organic (RDOC), and particulate organic (POC) carbons were analyzed using high-temperature combustion oxidation. The three streams (Cheongmi, Yanghwa, and Bokha) displayed high TOC concentrations during the rainy season because the accumulated organic substances from the dry season were washed away by rainfall. By contrast, Paldang Lake exhibited a substantial decrease in TOC concentration due to dilution, which was influenced by watershed and rainfall characteristics. Across all streams and lakes, dissolved organic carbon (DOC) accounted for the highest proportion, at 77.5% of TOC, with RDOC making up 91% of DOC and 71% of TOC. Although POC contributed a small annual proportion to annual TOC, the concentration rapidly increased during late spring and early summer, with increases of 40.403%, 25.99%, and 27.388% in Cheongmi, Yanghwa, and Bokha, respectively. Continuous monitoring of RDOC is essential to identify seasonal fluctuations and changes due to rainfall events. Furthermore, intensive POC management during the rainy season, particularly in May and June, is potentially economical and efficient for water quality management.
Keywords: dry season; rainfall; refractory organic substances; total organic carbon; wet season

1. Introduction

TOC and DOC organic carbons are increasingly emphasized as key indicators in water quality assessment. Traditional benchmarks such as Biochemical (BOD) and chemical (COD) oxygen demands have a long history of usage; however, their effectiveness as water quality indicators diminishes as levels of refractory organic matter increase (Gil *et al*. 2011). A better understanding of the properties of organic matter through TOC measurements (Kang and Gil 2023) is required along with more representative indicators of total organic load to provide a more comprehensive approach to water quality assessment (Hayakawa *et al*. 2019).

Human and industrial activities are the primarily source of nonbiodegradable organic (Steinbüchel 2005, Jean *et al*. 2019), which are classified as nonbiodegradable because of their resistance to natural degradation (Xuqing 2016). They are persistent pollutants in the environment, and can adversely affect aquatic ecosystems, water quality and habitat (Pruss 2015, Lin *et al*. 2010). The presence of these compounds in the food chain can also cause health problems in humans.

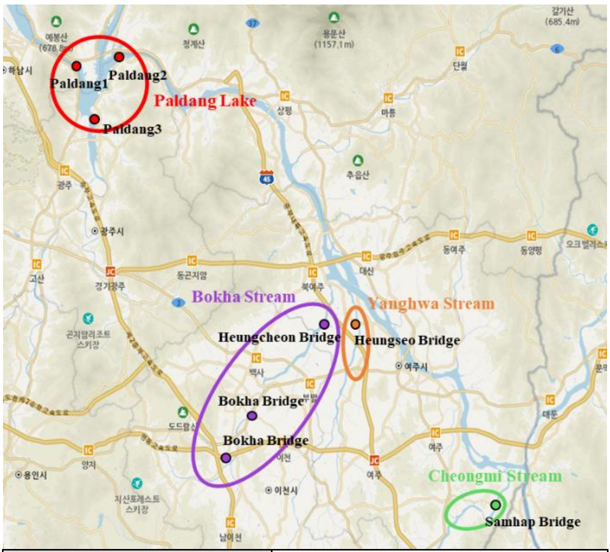
Seasonal changes, such as rainfall fluctuations, have a significant impact on the concentration of nonbiodegradable matter. Factors such as soil moisture, stream flow, and other hydrological parameters also fluctuate during rainfall events, thereby affecting the level of nonbiodegradable material (Li *et al*. 2005, Salim *et al*. 2019). The dynamic nature of nonbiodegradable substance concentrations in response to rainfall presents challenges for future environmental conservation and management efforts (Gomes and Wai 2015, Kim *et al*. 2019). Therefore, monitoring the concentration profiles of nonbiodegradable material during rainy and dry seasons is crucial, and rational strategies for effective mitigation must be developed (Kozak *et al*. 2019).

Typically, the proportion of particulate matter in streams tends to increase during the late spring and early summer, around May and June (Fan *et al*. 2012). Herein, Cheongmi Stream exhibited a decrease in POC ratios until May or June, complicating the prediction of particulate matter trends (Choi *et al*. 2020, Kim *et al*. 2014). In Paldang Lake, where water flows in from surrounding rivers, the flow rate increases significantly during rainfall, resulting in higher TOC concentrations (mg/L), which can introduce inaccuracies in organic matter assessments (MacQuarrie and Sudicky 1990). The lake's flow rate increases during rainfall, resulting in high concentration loads (Dunkerley 2008).

Considerably, the outflow of pollutants during rainfall causes remarkable monthly and seasonal changes in emissions. The characteristics of these outflows vary considering the regional characteristics such as climate,

*Corresponding author, Professor,
E-mail: kgil@seoultech.ac.kr

 ISSN: 2005-8624 (Print), 2092-7037 (Online)



Chungmi Stream	Samhap Bridge
Yanghwa Stream	Heungseo Bridge
Bokha Stream	Heungcheon Bridge
	Bokha Bridge
	Bokha Stream Bridge
Paldang Lake	Paldang1
	Paldang2
	Paldang3

Fig. 1 Monitoring Site and Division naming

topography, land-use type, soil, and watershed morphology, making prediction and quantification difficult (Park *et al*. 2008). Therefore, this study monitors and analyzes the fluctuations in various organic substance concentrations such as TOC, RDOC, and refractory particulate organic carbon (RPOC) by comparing the concentration and concentration load based on the watershed characteristics of three streams and one lake in the Namhan River system during the wet and dry seasons. This approach can facilitate the implementation of efficient and economical management strategies to address water quality changes owing to rainfall variability.

2. Materials and methods

Monitoring experiments were conducted seven times on three streams and one lake, covering both wet and dry seasons. The following water quality indicators were analyzed using the high-temperature combustion oxidation method, which allows for accurate measurement even in samples with high concentrations and significant amounts of suspended matter: TOC, RDOC, labile dissolved organic carbon (LDOC) and RPOC.

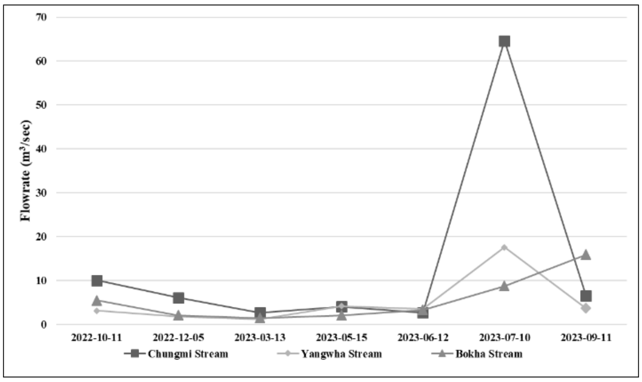
Monitoring was performed at the locations shown in Fig. 1 to analyze the concentrations of dissolved organic and nonbiodegradable organic substances in the Cheongmi, Bokha, and Yanghwa streams and Paldang Lake. For ease of monitoring and regional classification, the sites were named as illustrated in Fig. 1 Paldang 1, 2, and 3 in the lower reaches of Namhan River were grouped as Paldangho, and the Bokha, Yanghwa, and Cheongmi streams located near the upstream area were grouped according to their directions and branches. The Namhan River flows northwest from Chungju Lake, merging with major tributaries, such as the Cheongmi, Yanghwa, and Bokha Streams, and forming a watershed before entering Paldang Lake (Kim *et al*. 2005).

Notably, Paldang Lake receives inflow from three primary water systems: the Namhan River, Bukhan River, and Gyeongan Stream. The ratio of the lake's surface area to its watershed area is 618 (Ko *et al*. 2005). This characteristic classifies Paldang Lake as a stream-type lake, implying that its water quality and aquatic ecosystem can be considerably influenced by rainfall and pollutants from the watershed (Park *et al*. 2008).

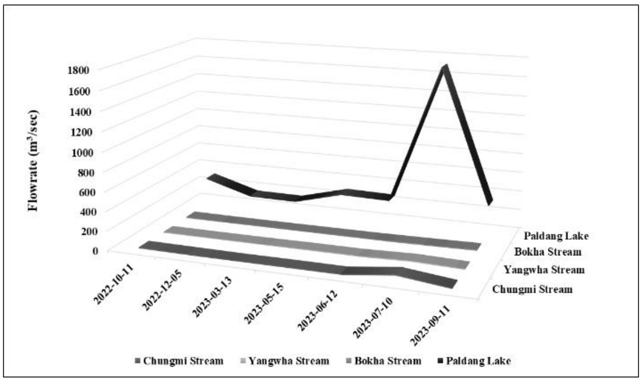
Total Organic Carbon-High Temperature Combustion Method was employed to measure the DOC in water. DOC and POC were separated using a 0.45 μm GF/C filter. Classification was based on the filtration process using filter paper. Substances passing through the filter paper were identified as DOC, while those remaining on the filter paper were classified as POC. DOC specifically used 0.45 μm GF/C filters, and the samples were predried at 500°C before filtration (APHA *et al*. 1998). This method included processing the sample with filter paper and subsequently subjecting it to a high-temperature combustor to oxidize it to carbon dioxide for quantification. Applicable to various water sources (e.g., surface water, groundwater, and wastewater), the quantification limit was 0.3 mg/L.

The filtrate sample underwent multiple washes using filter paper throughout the analysis process. A calibration curve is then established and measured to quantify both Non Purgeable Organic Carbon and additive (TC-IC). The result is expressed as DOC, and the measured value represents the total dissolved carbon minus the inorganic carbon. The value obtained by addition and subtraction corresponds to the amount of dissolved nonpurgeable organic carbon (DNPOC). RTOC represents the nonbio-degradable components, before measuring RDOC, samples were pretreated to ensure that only nonbiodegradable substances remained (Kim and Gil 2011). Considerably, samples were stored at 20°C for 28 days. Biodegradation occurs in a dark environment, causing most organic matter to decompose and leaving only nonbiodegradable components (Servais *et al*. 1999). After removing the biodegradable organic matter, only nonbiodegradable organic matter remained in the sample. RTOC was measured using the same methods as TOC and DOC, with RDOC being measured quantitatively and RPOC being calculated. RTOC was determined as the sum of RDOC and RPOC.

To distinguish between rainy and dry seasons, understanding the monthly organic matter load is essential. The monthly concentration loads of RDOC, LDOC, RPOC, and labile particulate organic carbon LPOC (all t/month) for each stream were calculated, following the monitoring schedule. The concentration load was derived based on the organic carbon concentration and flow data, calculated by



(a) Flowrates in the three sampled streams



(b) Flowrates in Paldang Lake compared with those of the sampled streams

Fig. 2 Comparison of Flowrate of Three Streams and Paldang Lake

multiplying the concentration by the flow rate. As the unit of volume is liters, and 1,000 L is equivalent to 1 m^3, the right side was multiplied by 1,000. finally, the units of concentration load were converted from (mg/s) to (tons/month).

$$Concentration(mg/L) \times flowrate(m^3/s) = 1000 \times Concentration\ load(mg/s) \quad (1)$$

Examining the flowrate changes during rainfall periods using a water environment information system revealed a significant impact of rainfall that occurred 2–3 days prior the subsequent flow rate. In response to these findings, this study computed the stream and lake flow rates by considering the past rainfall dates. The methodology involved creating rainfall graphs and averaging them through interpolation (Arnell *et al*. 1990).

According to the flowrate calculation method described above, the flowrate indicators of the three streams (Cheongmi, Yanghwa, and Bokha) and Paldang Lake are shown in Fig. 2. Fig. 2 (a) shows the flowrates during the monitoring period in the three streams, and (b) shows the difference in flowrates between Paldang Lake and the three streams by adding the flowrate of Paldang Lake. The reason for presenting two separate graphs is that Paldang Lake has a significantly higher flowrate compared to the three rivers, making it difficult to compare them in a single graph.

In many cases, the flow rate was unexpectedly unknown. In these cases, the flow rate can be calculated using the number of preceding dry season days, rainfall intensity, and amount of rainfall. In addition, the preceding rainfall index data, which is useful for reconstructing and simulating stream flow changes caused by rainfall in areas where flow data are lacking, can be used(Fedora and Beschta, 1989). The consistency and the accuracy of the research project will increase if the flow rate is accurately calculated using this method.

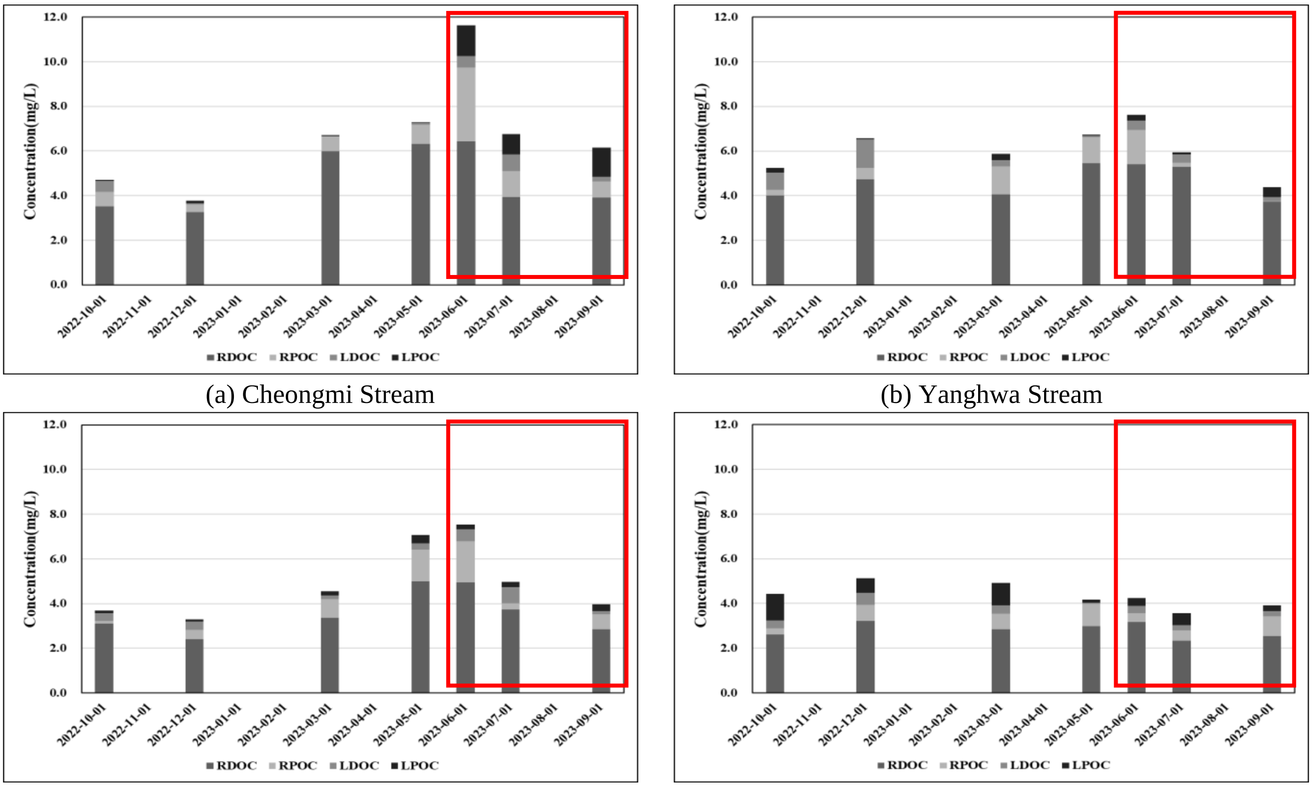
3. Results and discussion

3.1 Analysis of the runoff characteristics by stream during wet and dry seasons

Nonpoint source water quality controls may be necessary for achieving the goals of federal water quality control laws. Since 1972, the control of point source discharges has been leading to some improvements in the nation’s water quality (Thomas 1985, Letson 2019). However, although common pollutants, such as bacteria and oxygen-demanding waste, have decreased, the quality of the nation’s surface waters has not significantly improved relative to these point source declines. The period from June end to early September was identified as the wet season, and the red border in Fig. 3 indicates monitoring performed during the wet season (Ko *et al*. 2005). Nonpoint source contributions remain and are increasing (Letson 2019).

In Cheongmi Stream, the lowest recorded RTOC value of 3.613 mg/L was observed during the dry season in the second monitoring experiment period on December 1, 2022. In contrast, the highest RTOC value of 9.750 mg/L was recorded during the wet season in the fifth sampling period on June 12, 2023. For Yanghwa stream, the RTOC values ranged from 3.751 to 6.936 mg/L. The lowest value was recorded during the dry season, while the highest value was observed during the rainy period. In Bokha Stream, the RTOC values ranged from 2.839 to 6.798 mg/L, with the highest value recorded during the wet season. The concentrations of water quality indicators are shown in Fig. 3. After reaching a peak in summer, the concentrations decreased over the fall, followed by an increase in the spring because of the accumulation of organic substances during the winter season (Heo *et al*. 2017). This trend is consistent with previous studies that investigated the Namhan River water system, including Cheongmi, Yanghwa, and Bokha Streams and Paldang Lake (Gil *et al*. 2011).

The RTOC value of Paldang Lake was below 4 mg/L in all periods, but unlike other streams, the concentration was lower in the wet season compared to the dry season. This does not mean that the quantity of organic matter in Paldang Lake is low. Rather, this occurred because the concentration load, that is, the amount of organic matter, varies depending on the flow rate. As mentioned earlier, in a stream where water flows, the contaminants are washed away, and the TOC value increases as the flow rate increases. However, in lakes like Paldang Lake, where the water collected comes from surrounding rivers, the flow rate significantly increases, resulting in the TOC concentration (mg/L) that leads to an inaccurafte assessment of the level of organic matter.



(a) Cheongmi Stream (b) Yanghwa Stream

(c) Bokha Stream (d) Paldang Lake

Fig. 3 Values of organic matters by monitoring schedule

Paldang Lake is a site of water influx from upstream rivers. Fig. 2 illustrates the increase in flow rate of the lake during rainfall and expected periods of high concentration load (obtained by multiplying the concentration by the flow rate), which was the case here.

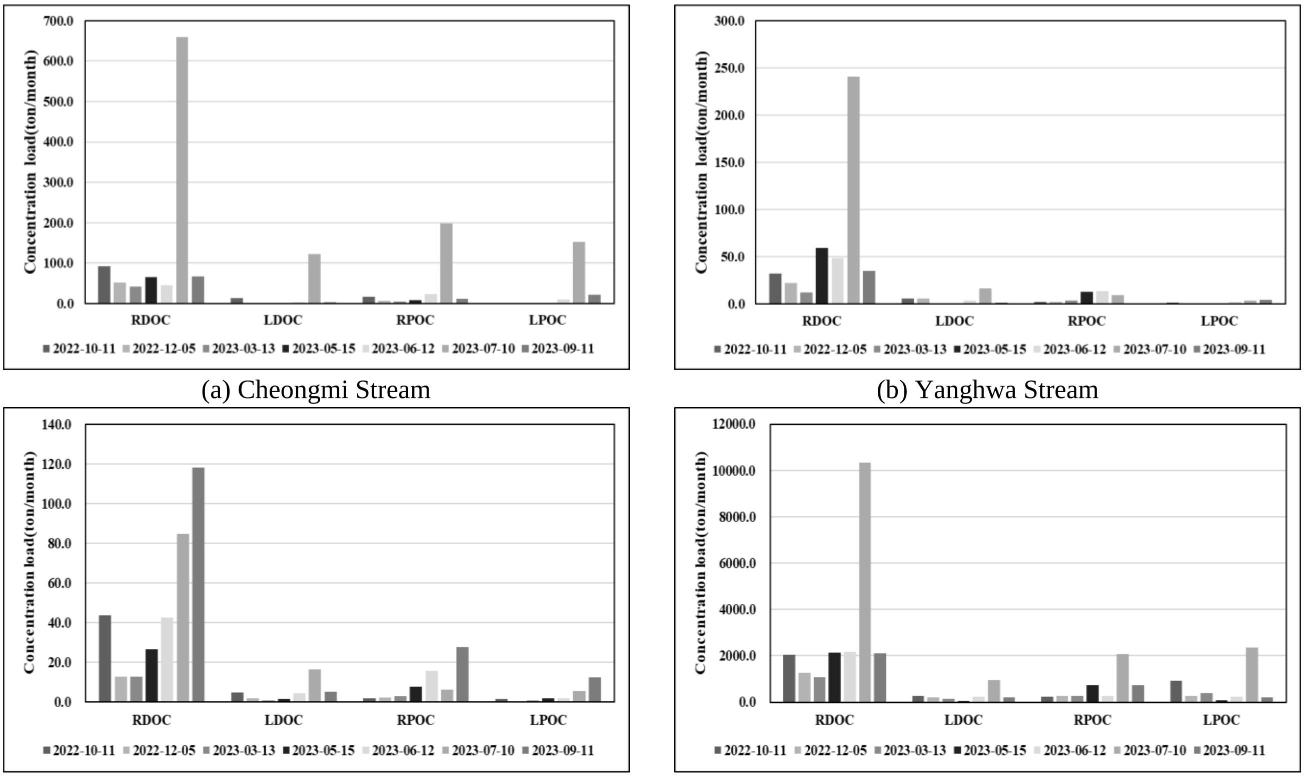
3.2 Comparison of the difference in concentration load of organic substances by stream during wet and dry seasons

Unlike the other sites, flow rate data was not available for Paldang Lake, but rainfall data was available, therefore, the flow rate was calculated using an interpolation method considering the flow rate data from the nearby Paldang Bridge and the characteristics of the rainfall that fell in the prior 2–3 days, a method previously employed in earlier work (Wagner *et al*. 2012).

Across all sites, DOC accounted for approximately 77.5% of TOC on average per year. Seasonally, the highest proportion was observed in winter, while the lowest proportion occurred in summer, which is consistent with existing studies (Lawacz 1977, Im and Gil 2023). Moreover, refractory dissolved organic carbon comprised an annual average of 71% of TOC, with RDOC making up about 91% of DOC and indicating that dissolved organic substances constitute a large proportion of the total organic matter, with a considerable amount being nonbiodegradable (Chen *et al*. 2017). The increase in organic substances, particularly dissolved nonbiodegradable ones, can lead to problems such as algae growth in streams used as water sources and affect the filtration process, thereby reducing the efficiency of water treatment (Heo *et al*. 2017). To effectively manage water quality with increasing TOC levels, focusing on controlling dissolved nonbiodegradable substances is essential, which represent the largest proportion of TOC.

Recognizing this, it is crucial to consider Therefore, understanding the discharge characteristics of RDOC, detected in larger amounts than RPOC, and developing appropriate measures based on additional monitoring experiments is crucial (Nguyen and Hur 2011, Hansell and Carlson 2013).

As shown in Fig. 4, the TOC concentration load was highest in July, the wet season, for all streams except Bokha. In July, the Bokha Stream experienced its second highest concentration load. Fig. 2 shows that the Bokha Stream had a maximum flow rate in September, which was approximately 1.82 times higher than in July. The difference in concentration load occurred due to heavy rainfall in September that washed a substantial amount of organic matter into the stream (Eimers *et al*. 2008). These monitoring results demonstrate the remarkable impact of rainfall on organic matter concentrations. In terms of concentration, the maximum TOC value in Paldang Lake, where organic matter concentration was low during the wet season, was15,754.14 t/month, which was approximately 8.4 times higher than the minimum value of 1,847.15t/ month in March (Gil *et al*. 2011). The TOC values representing the total amount of organic matter tended to increase in all watersheds during the wet season from May to July. Nonbiodegradable organic substances appeared to account for a large portion of nonpoint pollution sources



(a) Cheongmi Stream (b) Yanghwa Stream

(c) Bokha Stream (d) Paldang Lake

Fig. 4 Concentration load by stream and lake

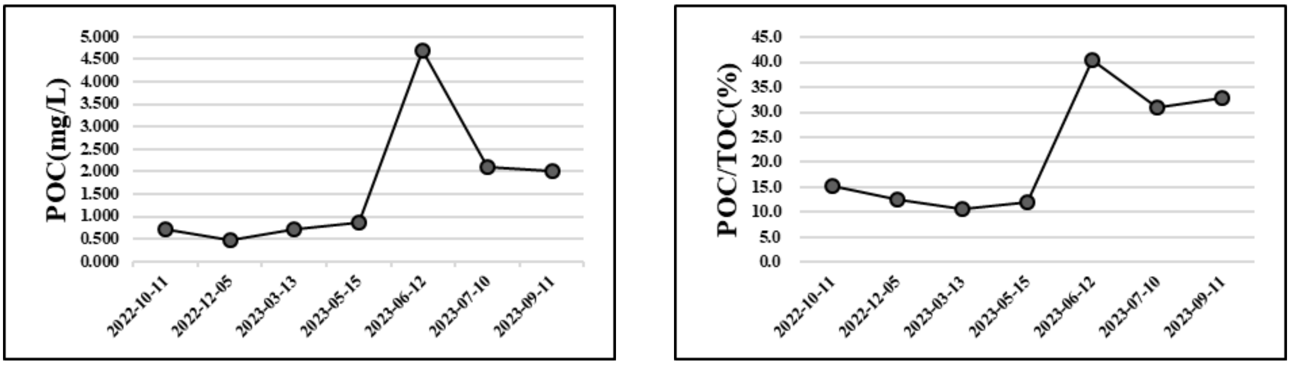
every month. The load on the POC rapidly increased in May and June. The graph in Fig. 4 shows that nonbiodegradable dissolved organic substances account for majority of the abovementioned nonpoint pollutants every month and implies the importance of managing the POC from May to July.

When managing the water quality, the monthly RDOC should be managed with utmost importance. The POC had minimal impact during the entire period. However, the load rapidly increased only during the wet season from May to July. Despite intensive management during this period, notable economic effects occurred. POC which is the sum of LPOC and RPOC is illustrated in the graph within Fig. 4. During the rainy season, the peak concentration loads were recorded as follows: Cheongmi Stream contained 350.3 t/month in July, Yanghwa Stream contained 16.09 t/month in June, Bokha Stream contained 40.37 t/month in September, and Paldang Lake contained 4,443.74 t/month in July. The minimum concentration loads during the four samplings in the dry season were 4.96, 2.58, 2.87, and 532.92 t/month in March, December, December, and December, for Cheongmi streams, Yanghwa streams, Bokha Streams, and Paldang Lake, respectively. Comparatively, the concentration loads measured during the rainy season were 70.63, 6.24, 14.06, and 8.34 times higher than that in the dry season, respectively.

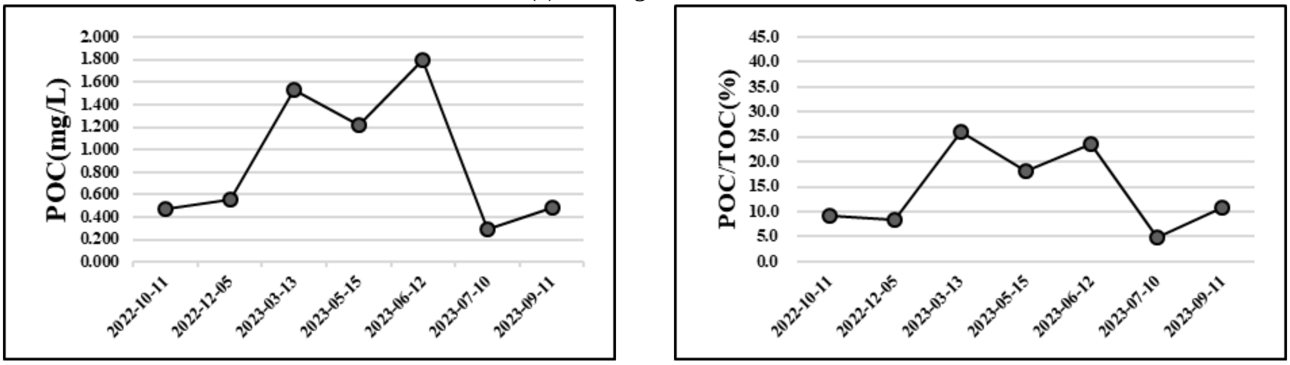
3.3 POC concentration and ratio by region according to wet and dry seasons

Paldang Lake experiences a significant increase in flow rate during the wet season. The precipitation data from July, when precipitation was the highest, were compared with the flow rates of Paldang Lake and the three streams (Fig. 2). The flowrate in Paldang Lake was 26.428, 97.199, and 195.08 times greater than that of Cheongmi, Yanghwa, and Bokha Streams, respectively. Hence, predicting behavior based solely on concentration is challenging, and the behavior of the recalcitrant organic substances must be determined through the concentration load(Joannis *et al*. 2015). Accordingly, Paldang Lake was excluded from the behavior analysis according to the particulate matter proportion and was not investigated. Fig. 5 shows the POC concentration load of the three streams and the ratio of POC to TOC, in which TOC is the sum of POC and DOC. In Fig. 5, the maximum POC/TOC values in the three streams were 40.403%, 25.99%, and 27.338%, with a ratio of <40% at most monitoring instances. In all streams, the POC/TOC ratio was highest during rainfall. In particular, Cheongmi and Yanghwa Streams reached their peak values on June 12, 2023, while Bokha Stream reached its second highest level. The corresponding concentration in Bokha Stream was 1.793 mg/L, which was higher than the value of 1.527 mg/L measured during the 6th monitoring period and had the highest POC/TOC ratio. All monitoring results revealed maximum concentrations in June, during the rainy season.

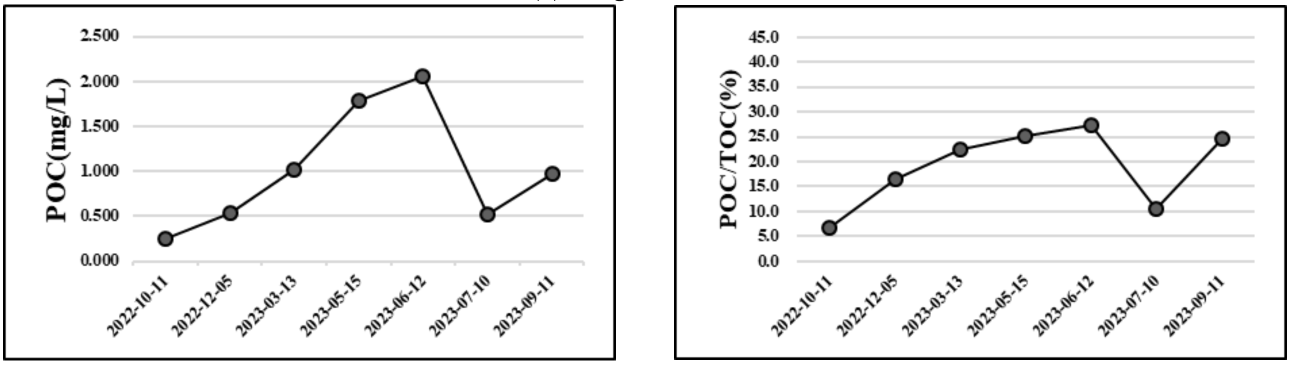
On average, the proportion of particulate matter increased toward late spring and early summer (May and June) (Golladay *et al*. 2000). However, in three streams studied in Korea, the POC ratio decreased until June or July, unlike the pattern observed here around May and June. This indicates that even within the same wet season, the



(a) Cheongmi Stream



(b) Yanghwa Stream



(c) Bokha Stream

Fig. 5 Values of POC(mg/L), POC/TOC(%) by monitoring schedule

POC ratio is highly variable and low POC concentrations may occur depending on the watershed characteristics and rainfall. When heavy rainfall causes increased flow into the stream, the concentration of particulate organic matter initially increases because of an abundant suspended sediments (Park *et al*. 2006). However, over an extended period of increasing flowrates due to heavy summer rain, the concentration of organic carbon gradually becomes diluted and decreases (Cauwet 2002). Future monitoring is necessary to accumulate and analyze such events.

When viewed as a whole, the POC/TOC ratio was smaller than that of DOC/TOC ratio. Therefore, it is better to intensively manage the POC in May and June during the wet season to achieve economic feasibility instead of managing it monthly (Bass *et al*. 2011, Dhillon and Inamdar 2013).

The concentration of organic matter, particularly RDOC, encompasses natural processes and human impacts on aquatic ecosystems. Monitoring and understanding changes in organic matter concentrations during dry and wet seasons can help identify pollution sources, assess ecosystem health, and efficiently and economically implement management strategies to conserve and restore water quality.

4. Conclusions

This study analyzed seasonal changes in concentration and concentration load in three streams (Cheongmi, Yanghwa, Bokha) and one lake (Paldang Lake), leading to three predominant conclusions.

• During the rainy season, RTOC values and TOC concentration loads increased rapidly in all three streams. In particular, organic matter concentrations peaked during the wet season, which is June and July. This peak is attributed to organic matter accumulation over the winter, which get washed into streams by spring and summer rainfall. Conversely, Paldang Lake had consistent RTOC values of

<4 mg/L throughout all periods, with lower organic carbon concentrations in the wet season than the dry season. As a stream-type lake, Paldang Lake receives water from three water systems: the Namhan River, Bukhan River, and Gyeongan Stream, so the flow rate is very large and the concentration can decrease during rainy season. Therefore, to accurately assess organic matter concentrations in Paldang Lake, measuring the concentration load to account for the large inflow of water from upstream rivers and the subsequent dilution effect is crucial.

• Monitoring confirmed that DOC comprises the majority of annual TOC, of which RDOC is the predominant component. DOC accounted for 77.5% of the annual average TOC, and the RDOC/DOC ratio was approximately 91%, with RDOC accounting for approximately 71% of TOC. RDOC consistently represented the largest proportion of organic matter each month, indicating the need for ongoing monthly monitoring to achieve long-term water quality improvement. Therefore, effective management of RDOC, which accounts for the majority of TOC, is the key to meeting water quality standards based on TOC concentrations.

• Although POC levels were generally low throughout the year, a sharp increase was observed during the rainy season in May and June. Rainfall causes large quantities of suspended particulate matter and sediment to flow into streams, leading to these increases. The POC/TOC ratio remained at an annual average of <25% and a maximum ratio of <40% in the three streams (Cheongmi, Yanghwa, and Bokha) during the entire monitoring period. Although POC comprises a small proportion of TOC throughout the year, its proportion in TOC increases rapidly during the rainy season from May to July. Therefore, intensive management of POC during the wet season is economically advantageous.

• This study systematically analyzed changes in organic matter concentration and its effects in each stream and lake, providing crucial fundamental data to develop practical management strategies for improving water quality. It will serve as an important reference for establishing and implementing future water quality management policies.

Acknowledgments

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

References

APHA, AWWA and WEF (1998), *Standard Method for Examination of Water and Wastewater*, Washington D.C., U.S.A.

Arnell, N.W., Brown, R.P. and Reynard, N.S. (1990), *Impact of Climatic Variability and Change on River Flow Regimes in the UK*, Institute of Hydrology, Wallingford, U.K.

Bass, A.M., Bird, M.I., Liddell, M.J. and Nelson, P.N. (2011), "Fluvial dynamics of dissolved and particulate organic carbon during periodic discharge events in a steep tropical rainforest catchment", *Limnol. Oceanogr.*, **56**(6), 2282-2292. https://doi.org/10.4319/lo.2011.56.6.2282

Cauwet, G. (2002), "DOM in the coastal zone. *Biogeochemistry of marine dissolved organic matter*.

Chen, S., Yoshitake, S., Iimura, Y., Asai, C. and Ohtsuka, T. (2017), "Dissolved organic carbon (DOC) input to the soil: DOC fluxes and their partitions during the growing season in a cool-temperate broad-leaved deciduous forest, central Japan", *Ecol. Res.*, **32**, 713-724. https://doi.org/10.1007/s11284-017-1488-6

Choi, H., Ryu, I., Park, M., Song, Y., Yu, S. and Kim, S. (2020), "Analysis of the water circulation structure in the Paldang reservoir, South Korea", *Appl. Sci.*, **10**(19), 6822. https://doi.org/10.3390/app10196822

Dhillon, G.S. and Inamdar, S. (2014), "Storm event patterns of particulate organic carbon (POC) for large storms and differences with dissolved organic carbon (DOC)", *Biogeochemistry*, **118**, 61-81. https://doi.org/10.1007/s10533-013-9905-6

Dunkerley, D. (2008), "Rain event properties in nature and in rainfall simulation experiments: A comparative review with recommendations for increasingly systematic study and reporting", *Hydrol. Proc.*, **22**(22), 4415-4435. https://doi.org/10.1002/hyp.7045

Eimers, M.C., Buttle, J. and Watmough, S.A. (2008), "Influence of seasonal changes in runoff and extreme events on dissolved organic carbon trends in wetland-and upland-draining streams. *Canadian J. Fish. Aqua. Sci.*, **65**(5), 796-808. https://doi.org/10.1139/f07-194

Fan, X., Cui, B., Zhang, K., Zhang, Z. and Shao, H. (2012), "Water quality management based on division of dry and wet seasons in Pearl River Delta, China", *Clean Soil, Air, Water*, **40**(4), 381-393. https://doi.org/10.1002/clen.201100123

Fedora, M.A. and Beschta, R.L. (1989), "Storm runoff simulation using an antecedent precipitation index (API) model", *J. Hydrol.*, **112**(1-2), 121-133. https://doi.org/10.1016/0022-1694(89)90184-4

Gil, K., Kim, T. and Jung, M.S. (2011), "Runoff characteristics of refractory organic matters from South-Han river watershed during rainfall event and dry season", *J. Korean Soc. Water Environ.*, **27**(3), 306-313. https://doi.org/10.15681/KSWE.2011.27.3.7

Golladay, S.W., Watt, K., Entrekin, S. and Battle, J. (2000), "Hydrologic and geomorphic controls on suspended particulate organic matter concentration and transport in Ichawaynochaway Creek, Georgia, USA", *Archiv für Hydrobiologie*, **149**(4), 655-678.

Gomes, P.I. and Wai, O.W. (2015), "In-stream physical heterogeneity, rainfall aided flushing, and discharge on stream water quality", *Water Environ. Res.*, **87**(8), 758-768. https://doi.org/10.2175/106143015X14362865225997

Hansell, D.A. and Carlson, C.A. (2013), "Localized refractory dissolved organic carbon sinks in the deep ocean", *Global Biogeochem. Cy.*, **27**(3), 705-710. https://doi.org/10.1002/gbc.20067

Hayakawa, K., Hirose, Y., Okamoto, T., Hichiri, S., Ohara, T., Noto, K. and Inoue, S. (2019), "Modification of analytical procedure for determining total organic carbon in lake waters using a TOC analyzer", *J. Japan Soc. Water Environ.*, **42**(6), 259-267. https://doi.org/10.2965/jswe.42.259

Im, J. and Gil, K. (2023), "Characteristics of micro-plastics in stormwater sediment basin: Case study of J wetland", *Membr. Water Treat.*, **14**(4), 147. https://doi.org/10.12989/mwt.2023.14.4.147

Jeon, J., Choi, H., Shin, D. and Kim, L.H. (2019), "Installation and operation of automatic nonpoint pollutant source measurement system for cost-effective monitoring", *Membr. Water Treat.*, **10**(1), 99-104. https://doi.org/10.12989/mwt.2019.10.1.099

Joannis, C., Hannouche, A. and Chebbo, G. (2015), "An assessment of the respective contributions of flow-rate and concentration variations to mass discharge variations at the outlets of two combined catchments during rain events", *Urban Water J*., **12**(8), 653-659. https://doi.org/10.1080/1573062X.2014.939662

Kang, C. and Gil, K. (2023), "Constructing an Internet of things wetland monitoring device and a real-time wetland monitoring system", *Membr. Water Treat*., **14**(4), 155. https://doi.org/10.12989/mwt.2023.14.4.155

Kim, D., Kim, J., Joo, H., Han, D. and Kim, H.S. (2019), "Future water quality analysis of the Anseongcheon River basin, Korea under climate change", *Membr. Water Treat*., **10**(1), 1-11. https://doi.org/10.12989/mwt.2019.10.1.001

Kim, D.W., Jang, M.J. and Han, I.S. (2014), "Determination of focused control pollutant source by analysis of pollutant delivery characteristics in unit watershed upper Paldang lake", *J. Korean Soc. Environ. Eng*., **36**(5), 367-377. https://doi.org/10.4491/KSEE.2014.36.5.367

Kim, J.K., Lee, S.H., Bang, H.H. and Hwang, S.O. (2009), "Characteristics of algae occurrence in Lake Paldang", *J. Korean Soc. Environ. Eng*., **31**(5), 325-331.

Kim, T. and Gil, K. (2011), "Runoff characteristics of refractory organic matters from Kyongan river watershed during rainfall event and dry season", *J. Korean Soc. Water Environ*., **27**(4), 397-404. https://doi.org/10.15681/KSWE.2011.27.4.2

Ko, J.W., Baek, H.J. and Kwon, W.T. (2005), "The characteristics of precipitation and regionalization during rainy season in Korea", *J. Korean Meteorol. Soc*., **41**, 101-114.

Kozak, C., Fernandes, C.V.S., Braga, S.M., do Prado, L.L., Froehner, S. and Hilgert, S. (2019), "Water quality dynamic during rainfall episodes: integrated approach to assess diffuse pollution using automatic sampling", *Environ. Monitor. Assess*., **191**, 1-13. https://doi.org/10.1007/s10661-019-7537-6

Lawacz, W. (1977), "Dissolved and particulate organic carbon (DOC and POC) in ecological studies", *Acta Hydroch. Hydrob*., **5**(4), 363-367. https://doi.org/10.1002/aheh.19770050405

Letson, D. (2019), *Point/Nonpoint Source Pollution Reduction Trading: An Interpretive Survey*, in *The Economics of Water Quality*, Routledge, London, U.K.

Li, F., Yuasa, A., Muraki, Y. and Matsui, Y. (2005), "Impacts of a heavy storm of rain upon dissolved and particulate organic C, N and P in the main river of a vegetation-rich basin area in Japan", *Sci. Total Environ*., **345**(1-3), 99-113. https://doi.org/10.1016/j.scitotenv.2004.11.004

Lin, Y.F., Jing, S.R., Lee, D.Y., Chang, Y.F. and Sui, H.Y. (2010), "Constructed wetlands for water pollution management of aquaculture farms conducting earthen pond culture", *Water Environ. Res*., **82**(8), 759-768. https://doi.org/10.2175/106143010X12609736966685

MacQuarrie, K.T.B. and Sudicky, E.A. (1990), "Simulation of biodegradable organic contaminants in groundwater: 2. Plume behavior in uniform and random flow fields", *Water Resour. Res*., **26**(2), 223-239. https://doi.org/10.1029/WR026i002p00223

Nguyen, H.V.M. and Hur, J. (2011), "Tracing the sources of refractory dissolved organic matter in a large artificial lake using multiple analytical tools", *Chemosphere*, **85**(5), 782-789. ttps://doi.org/10.1016/j.chemosphere.2011.06.068

Park, J.H., Kong, D.S. and Min, K.S. (2008), "Delivered pollutant loads of point and nonpoint source on the upper watershed of Lake Paldang-case study of the watershed of Namhan River and Gyeongan Stream", *J. Korean Soc. Water Environ*., **24**(6), 750-757.

Park, J.K., Kim, E.S., Kim, K.T., Cho, S.R. and Park, Y.C. (2006), "Organic carbon behavior and distribution in the Mankyoung River Estuary", *J. Korean Soc. Mar. Environ. Eng*, **9**(3), 131-140.

Pruss, A. (2015), "Removal of organic matter from surface water during coagulation with sludge flotation and rapid filtration–a full-scale technological investigation", *Water Sci. Technol*., **71**(4), 645-652. https://doi.org/10.2166/wst.2014.514

Salim, I., Paule-Mercado, M.C., Sajjad, R.U., Memon, S.A., Lee, B.Y., Sukhbaatar, C. and Lee, C.H. (2019), "Trend analysis of rainfall characteristics and its impact on stormwater runoff quality from urban and agricultural catchment", *Membr. Water Treat*., **10**(1), 45-55. https://doi.org/10.12989/mwt.2019.10.1.047

Servais, P., Garnier, J., Demarteau, N., Brion, N. and Billen, G. (1999), "Supply of organic matter and bacteria to aquatic ecosystems through waste water effluents", *Water Res*., **33**(16), 3521-3531. https://doi.org/10.1016/S0043-1354(99)00056-1

Steinbüchel, A. (2005), "Non-biodegradable biopolymers from renewable resources: Perspectives and impacts", *Curr. Opin. Biotechnol*., **16**(6), 607-613. https://doi.org/10.1016/j.copbio.2005.10.011

Thomas, L.M. (1985), "Management of nonpoint-source pollution: What priority?", *J. Soil Water Conserv*., **40**(1), 8-8.

Wagner, P.D., Fiener, P., Wilken, F., Kumar, S. and Schneider, K. (2012), "Comparison and evaluation of spatial interpolation schemes for daily rainfall in data scarce regions", *J. Hydrol*., **464**, 388-400. https://doi.org/10.1016/j.jhydrol.2012.07.026

Xuqing, L., Yayun, L., Chao, L., Li, Z., Hao, Y., Chao, F. and Ashraf, M.A. (2016), "Identification of residual non-biodegradable organic compounds in wastewater effluent after two-stage biochemical treatment", *Open Life Sci*., **11**(1), 396- 401. https://doi.org/10.1515/biol-2016-0053

JL