JOWRM

Journal of Water Resources Management

Journal homepage: https://journal.water.gov.my

e-ISSN: 2811-3578

Study of Sustainable Solution to Rehabilitate and Conserve The Water System of The Upcycle Park River in Bandar Perda, Penang

Naviin Naidu[1,a], Mohd Remy Rozainy Mohd Arif Zainol[2,b]

[1]School of Civil Engineering, Engineering Campus Tuanku Syed Sirajuddin, Universiti Sains Malaysia (USM), Nibong Tebal, Penang 14300, MALAYSIA

[2]School of Civil Engineering, Engineering Campus Tuanku Syed Sirajuddin, Universiti Sains Malaysia (USM), Nibong Tebal, Penang 14300, MALAYSIA

*Corresponding Author

Email: [a]naviinnaidu@student.usm.my, [b]ceremy@usm.my

Received 02 Mac 2026;
Accepted 23 Jun 2026;
Available online 30 Jun 2026

Abstract: Urban rivers in developing areas are increasingly exposed to pollution from stormwater runoff, wastewater discharge, and human activities, posing risks to ecological health and public safety. The Upcycle Park River at Seberang Perai Upcycle Park, Malaysia's first upcycle park, serves as a community-driven sustainability initiative but suffers water quality deterioration. This study assessed seasonal variations in water quality from September to November 2024 using in-situ measurements for pH, temperature, and dissolved oxygen, and laboratory analyses for suspended solids, BOD, COD, and nutrients. Water quality was evaluated using the DOE Water Quality Index (WQI) and compared to NLWQS Category D standards. Results indicate polluted conditions (Class III–IV), with dry season DO as low as 0.45 mg/L, ammoniacal nitrogen up to 2.41 mg/L, and total phosphorus reaching 52.1 mg/L, reflecting stagnation and oxygen stress. Wet season runoff elevated turbidity (up to 94 NTU), suspended solids (130 mg/L), nutrients (NH_3-N <26.01 mg/L, TP <27.6 mg/L), and selected heavy metals (Hg 0.024 mg/L, Ni 0.171 mg/L), showing impacts from stormwater and urban discharge. Integrated management strategies including wastewater control, stormwater mitigation, and nature-based solutions are recommended to restore ecological health and ensure sustainable water quality.

Keywords: WQI, NLWQS, Class, Dry, Wet

1. Introduction

The Seberang Perai Upcycle Park, located in Bandar Perda, Penang, is Malaysia's first upcycle park, showcasing sustainability and community-driven conservation [2]. Covering about 9,684.5 m², it features a pond and green space serving around 20,500 residents, with structures made from repurposed materials like old tires, pallets, and plastic bottles [12]. Despite being a model for sustainable urban infrastructure, the Upcycle Park River faces serious water quality issues, with high levels of BOD, COD, ammoniacal nitrogen, and coliform bacteria exceeding Malaysia's National Water Quality Standards [3,7]. The declining quality of the river's water is significantly worsened by urban runoff, poor wastewater treatment, and a lack of stringent environmental regulations, highlighting a pressing issue for sustainable management of urban water resources [1].

The study seeks to propose sustainable solutions for the rehabilitation and conservation of the Upcycle Park River in response to these challenges [9]. This study aims to improve water quality, foster biodiversity, and guarantee lasting ecological resilience through the integration of technological advancements, regulatory frameworks, and community involvement [10].

2. Water Quality Index (WQI)

A simpler and uniform assessment of the state of water quality is made possible by the Water Quality Index (WQI), a standardised instrument that converts several water quality criteria into a single composite result. Its main objective is to offer an initial evaluation of a water body's adherence to national water quality requirements for each of the five beneficial use groups. WQI is a useful tool for tracking trends and guiding choices about the management of water resources, even if it is not meant to be a perfect indication of pollution or ecological health.

A mix of physical, chemical, and biological properties are used to evaluate the quality of water. The WQI method is used in Malaysia by the Department of Environment (DOE) and is based on six fundamental parameters: pH, dissolved

**Corresponding author:* ceremy@usm.my
2026 JPS Publishing. All right reserved.

oxygen (DO), ammoniacal nitrogen (NH_3-N), suspended solids (SS), chemical oxygen demand (COD), and biochemical oxygen demand (BOD).

Rivers are categorised into Classes I through V, which range from pristine to highly contaminated conditions, based on an analysis of water quality data acquired from the Department of Environment Malaysia. Furthermore, rivers may be generically classified as Clean, Slightly Polluted, or Polluted based on WQI values, which facilitates efficient environmental planning and restoration initiatives.

Table 1 - Water Quality Index (WQI) reference according to DOE

Parameters	WQI	Classification
Class I	> 92.7	Clean (80 - 100)
Class II	76.5 - 92.7	
Class III	51.9 - 76.5	Slightly Polluted (60 - 80)
Class IV	31.0 - 51.9	Polluted (0 - 59)
Class V	< 31.0	

3. National Lake Water Quality (NLWQS) Criteria and Standard

The National Water Resources Council Malaysia (2015) created the National Lake Water Quality Criteria and Standards (NLWQS), which are used in this study as a guide to assess the water quality of the Upcycle Park River in Bandar Perda. The NLWQS offers precise standards for evaluating lake and pond water bodies according to their ecological significance and intended usage. principal contact recreation (Category A), secondary contact recreation (Category B), biodiversity conservation (Category C), and fundamental aquatic life and ecosystem protection (Category D) are the four principal classifications into which it divides water bodies.

Table 2 - Description of categories

Categories	Description
Category A	Lakes that are managed in which the water to be used for recreational purposes - primary body contact such as swimming, diving and kayaking
Category B	Lakes used for recreational purpose - secondary body contact such as boating and cruising. Swimming is not allowed in this category of lakes
Category C	The lakes are meant for the preservation of aquatic life and biodiversity
Category D	Lakes managed for minimum preservation of good aquatic life in the lakes It applies good management practice of lakes

The river's adherence to national lake water quality criteria was evaluated by comparing each parameter result to the threshold values specified under NLWQS Category D. Degradation of water quality was indicated by parameters that were found to be over allowable limits, necessitating specific mitigating measures. This categorisation facilitates the creation of restoration programs that complement fundamental objectives for ecosystem conservation. For that purpose, **Table 2** shows the parameters and criteria under Category D.

4. Study Site and Methods

4.1 Study Area

The study offers environmental, social, and economic benefits by improving water quality, reducing pollutants, restoring biodiversity, and enhancing flood resilience. It also supports recreation, eco-tourism, and community health while aligning with Sustainable Development Goals (SDG 6, 11, and 15).

The study focuses on Upcycle Park River in Bandar Perda, Pulau Pinang, within Seberang Perai, Penang, Malaysia. The area covers roughly 2.47 km², extending from Bandar Perda Lake (5°22'14.6"N 100°25'54.8"E) to Sungai Juru (5°22'15"N 100°25'23"E). Traversing an urbanised setting, the river holds ecological and social importance, making it a vital focus for sustainable water management and restoration



Fig. 1 – Location of the Upcycle Park Bandar Perda, Seberang Perai, Penang, Malaysia

4.2 Sampling Method

Water sampling was conducted in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 2012) using grab sampling techniques. Sampling was carried out twice monthly from September to November 2024 under both dry and wet seasonal conditions. A total of six sampling events were completed, comprising four dry-season datasets (29 September, 23 October, 6 November, and 20 November 2024) and two wet-season datasets (11 September and 9 October 2024).

Eight sampling stations (P1–P8) were established along the Upcycle Park River, extending from the inlet of Tasik Bandar Perda to the outlet of Sungai Juru. At each station, water samples were collected in clean polyethylene bottles and preserved according to APHA (2012) requirements prior to laboratory analysis.

In-situ measurements of temperature, pH, dissolved oxygen (DO), conductivity, and salinity were conducted using a Hanna Multiparameter Sonde. The instrument was calibrated before each sampling campaign using certified standard solutions following the manufacturer's recommendations. pH calibration was performed using pH 4.0, 7.0, and 10.0 buffer solutions, while conductivity calibration was conducted using standard conductivity solutions.

Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Ammoniacal Nitrogen (NH_3-N), Nitrate (NO_3-N), Total Phosphorus (TP), and heavy metals were analysed according to APHA (2012) Standard Methods. Quality assurance and

quality control (QA/QC) procedures included instrument calibration, duplicate analyses, method blanks, and laboratory verification using certified reference standards to ensure analytical accuracy and reliability.



Fig. 2 – Distribution of sampling location from Tasik Bandar Perda (upstream) to Sungai Juru (downstream)

Table 3 - Location of Sampling Points

Location	Sampling Point Name	Coordinate
Inlet Tasik Bandar Perda	P1	5.372989 100.435664
Tasik Bandar Perda	P2	5.371514 100.433385
Tasik Bandar Perda	P3	5.371456 100.432715
Outlet Tasik Bandar Perda	P4	5.371416 100.431774
Outlet Tasik Bandar Perda	P5	5.370780 100.431824
Inlet Sungai Juru	P6	5.370617 100.431311
Middle Sungai Juru	P7	5.370162 100.426887
Outlet Sungai Juru	P8	5.371486 100.422748

4.3 Statistical Analysis

Descriptive statistical analyses were conducted using Microsoft Excel. Mean values and seasonal trends were evaluated for all measured parameters. Comparative analysis between dry and wet seasons was performed by examining changes in parameter magnitude and spatial distribution across the eight sampling stations. Seasonal differences were interpreted based on observed trends relative to the National Lake Water Quality Standards (NLWQS) and Department of Environment (DOE) Water Quality Index (WQI) classification.

5. Results and Discussion

Wet season samples (11 September 2024 and 9 October 2024) coincided with heavy rainfall, increasing stormwater runoff from surrounding commercial, industrial, and residential areas. This runoff often carried suspended solids, nutrients, organic debris, and microbiological pollutants, causing a sharp rise in pollutant concentration. Dry season samples (29 Sept 2024, 23 Oct 2024, 6 Nov 2024, and 20 Nov 2024) reflected low flow rates, reduced dilution capacity, and prolonged pollutant retention. Direct human activities such as sewage discharge, greywater runoff, and dumping were more dominant pollution sources, with higher concentrations of coliform bacteria, ammoniacal nitrogen, and BOD due to evaporation and stagnation

5.1 Dry Season

Based on the Water Quality Index (WQI), the Upcycle Park River generally exhibits poor water quality conditions, with most sampling locations classified as Class IV (Polluted). According to DOE's categorisation criteria, WQI values in this class indicate significant deterioration of the water quality, rendering the impacted locations unsafe for recreational use for body contact and endangering aquatic life.

Table 4 – Analysis parameter for water quality based on NLWQS during dry season

Parameters	Range	NLWQS (Category D)
pH	6.28 - 7.01	5.5-9.0
Temperature (°C)	27.14 - 32.00	28
Conductivity (µS/cm)	202 - 763	5000
Salinity (mg/ℓ)	0.1 - 0.36	>1
DO (mg/ℓ)	0.45 - 4.93	3.3 - 10.3
DO Saturation (%)	5.3 - 63.9	40 - 130
Turbidity (NTU)	6 - 26	250
Total Suspended Solid (mg/ℓ)	8 - 57	>200
Colour (TCU)	12 - 40	300
Oil and Grease (mg/ℓ)	ND	1.5
Chlorophyll (µg/ℓ)	< 0.013	25
NH_3-N	0.28 - 2.41	< 2.7
Nitrate (NO3-N) (mg/ℓ)	< 22.86	10
TP (mg/ℓ)	< 52.1	0.05
Arsenic (As) (mg/ℓ)	< 0.018	0.4
Cadmium (Cd) (mg/ℓ)	< 0.004	0.01
Lead (Pb) (mg/ℓ)	< 0.049	0.05
The Mercury (Hg) (mg/ℓ)	ND <0.001	< 0.001
Nickel (Ni) (mg/ℓ)	< 0.067	0.05

Note:
ND: Not detected

The water quality parameters measured at various sampling points generally fall within the acceptable limits of the National Lake Water Quality Standards (NLWQS), with pH, conductivity, and salinity showing no significant concerns. However, temperature slightly exceeds the standard of 28°C, and Dissolved Oxygen (DO) levels fall below the required range, indicating potential oxygen depletion in the water. The Turbidity and TSS values are permissible in NLWQS threshold Strong Total Phosphorus (TP) and NH_3-N levels exceed the standards at most sampling points, suggesting nutrient pollution and significant contamination. Although arsenic, cadmium, and lead concentrations remained within acceptable limits, elevated mercury and nickel concentrations were detected at several sampling locations, indicating localized heavy metal contamination.

5.2 Wet Season

The majority of sampling locations along the Upcycle Park River were categorised as polluted, according to the analysis of water quality data gathered during the wet season, specifically on 11 Sep 2024, and 9 Oct 2024. Water Quality Index (WQI) values consistently fell within Class III and Class IV categories under the DOE classification system. These findings point to a significant degree of environmental deterioration that is probably caused by higher pollution loading during rainstorm episodes.

Table 5 – Analysis parameter for water quality based on NLWQS during wet season

Parameters	Range	NLWQS (Category D)
pH	6.31 - 6.90	5.5-9.0
Temperature (°C)	26.89 - 30.26	28
Conductivity (µS/cm)	97 - 529	5000
Salinity (mg/ℓ)	0.04 - 0.25	>1
DO (mg/ℓ)	1.0 - 5.3	3.3 - 10.3
DO Saturation (%)	22.8 - 60.4	40 - 130
Turbidity (NTU)	13 - 94	250
Total Suspended Solid (mg/ℓ)	9 - 130	>200
Colour (TCU)	11 - 45	300
Oil and Grease (mg/ℓ)	ND	1.5
Chlorophyll (µg/ℓ)	< 0.008	25
NH_3-N	< 26.01	< 2.7
Nitrate (NO3-N) (mg/ℓ)	<18.22	10
TP (mg/ℓ)	< 27.6	0.05
Arsenic (As) (mg/ℓ)	< 0.022	0.4
Cadmium (Cd) (mg/ℓ)	ND <0.001	0.01
Lead (Pb) (mg/ℓ)	< 0.175	0.05
The Mercury (Hg) (mg/ℓ)	0.024	< 0.001
Nickel (Ni) (mg/ℓ)	0.171	0.05

Note:
ND: Not detected

Based on the comparison with NLWQS, most parameters, including pH, conductivity, and salinity, fall within the acceptable limits, indicating good water quality. However, Dissolved Oxygen (DO) levels are below the required range of 3.3 to 10.3 mg/ℓ, suggesting potential oxygen depletion. Total Phosphorus (TP) consistently exceeds the standard of 0.05 mg/ℓ, indicating nutrient pollution, while Mercury (Hg) and Lead (Pb) concentrations are a concern at certain sampling points. NH_3-N and Nickel (Ni) levels exceed standards at some points, showing contamination, but Arsenic (As) and Cadmium (Cd) remain within acceptable limits. Overall, while most parameters are acceptable, nutrient pollution and heavy metals remain a concern.

5.3 Comparison Between Dry and Wet Season

As shown in **Fig. 3**, pH levels were very consistent throughout all sample stations in both seasons, with only modest variations between upstream and downstream locations. The closeness of the dry and wet season profiles indicates that rainfall had little effect on the river's acid-base balance. The highest pH values during the dry season were recorded at P2 and P8. However, pH remained within the acceptable NLWQS range in both seasons, indicating that seasonal rainfall had minimal influence on the acid-base characteristics of the river.

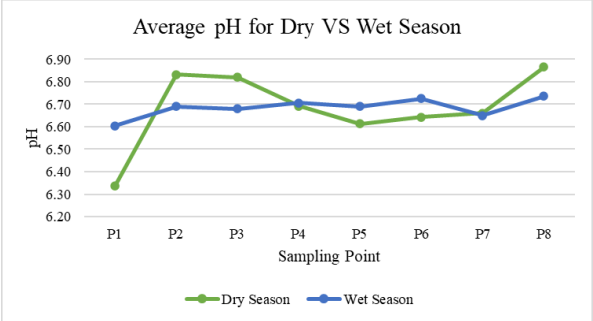

Fig. 3 – Spatial variation of average pH values during dry and wet seasons at sampling points P1–P8

Fig. 4 shows that average water temperatures remained above the NLWQS requirement of 28°C for both seasons. The dry season profile showed the highest temperature at P4, exceeding 30°C, indicating enhanced thermal heating under low-flow circumstances. In comparison, the wet season profile was somewhat lower but showed significant thermal spikes at downstream sites such as P5 and P7, which may be associated with thermal loading from impervious urban surfaces such as roads, parking areas, and nearby developments.

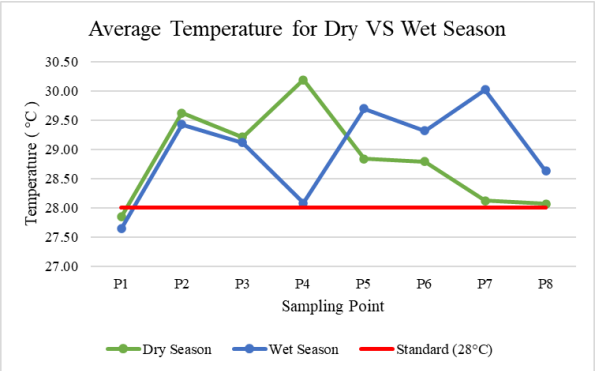

Fig. 4 – Comparison of average water temperature during dry and wet seasons relative to the NLWQS threshold

Conductivity and salinity exhibited similar spatial patterns, reflecting the strong relationship between dissolved ionic concentration and salinity levels, as shown in **Fig. 5** and **Fig. 6**. Both indicators were continuously higher during the dry season, peaking at upstream station P1 before gradually decreasing downstream. The wet season profiles were substantially lower and followed the dry season trend, however there was a noticeable reduction dilution at P4, indicating that rainfall-induced dilution reduced the concentration of dissolved ions during the wet season.

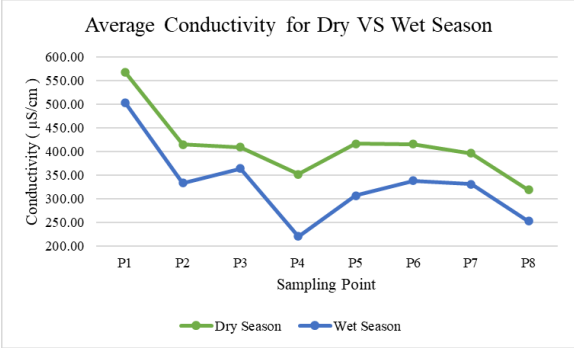

Fig. 5 – Comparison of average conductivity values during dry and wet seasons at sampling stations P1–P8

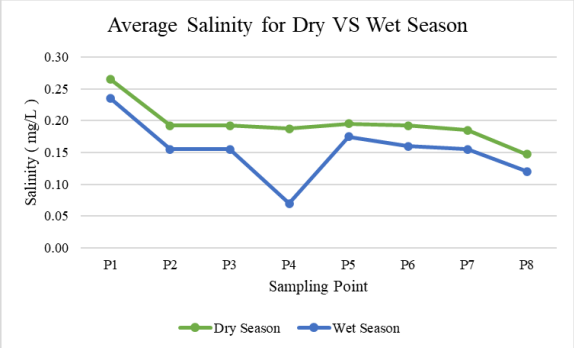

Fig. 6 – Comparison of average salinity values during dry and wet seasons at sampling stations P1–P8

Saturation percentages and dissolved oxygen levels exhibited substantial spatial variation, often falling below the necessary NLWQS, as **Fig. 7** and **Fig. 8** illustrate. The dry and wet season trends overlapped at several sampling stations; for example, the dry season sank to a critical low at P1 then jumped substantially at P2, showing stagnant flow conditions, combined with transient algal activity. In contrast, the wet season profile recovered at P1 owing to stormwater reaeration but dropped significantly at P2 and P4, indicating that stormwater runoff likely transported organic matter and oxygen-demanding substances into the river system.

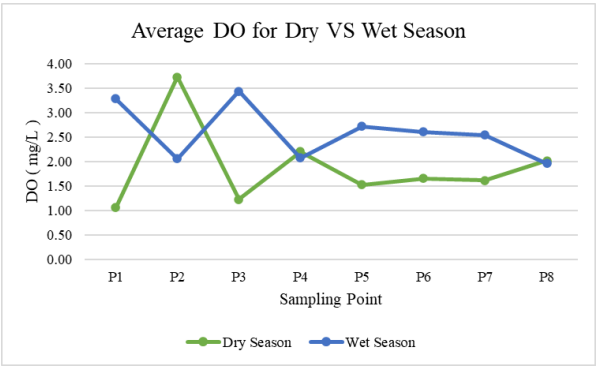

Fig. 7 – Spatial variation of average dissolved oxygen (DO) concentrations during dry and wet seasons at sampling stations P1–P8.

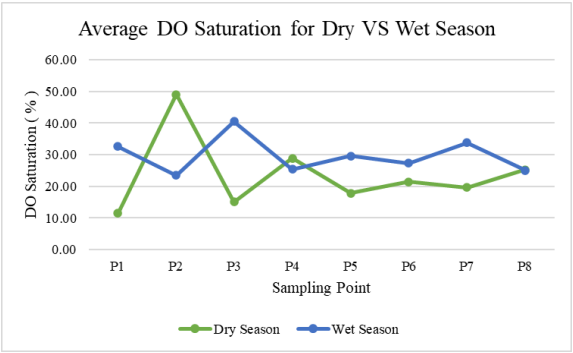

Fig. 8 – Spatial variation of average dissolved oxygen saturation percentages during dry and wet seasons at sampling stations P1–P8.

Overall, conductivity, salinity, turbidity, total suspended solids (TSS), and nutrient concentrations were generally higher during the wet season due to increased stormwater runoff from surrounding urban catchments. In contrast, dissolved oxygen (DO) remained consistently low during both seasons, indicating persistent oxygen stress within the river system. The results suggest that while wet-season rainfall enhanced dilution of some dissolved constituents, it simultaneously increased the transport of sediments, nutrients, and pollutants into the river. These findings demonstrate that seasonal hydrological conditions play a significant role in controlling water quality dynamics within the Upcycle Park River.

The observed seasonal variations are consistent with findings reported in other urban rivers in Malaysia. Studies conducted in Sungai Pinang, Penang, and the Klang River Basin reported elevated nutrient concentrations, suspended solids, and pollutant loading during rainfall events due to increased urban runoff. Similarly, low dissolved oxygen concentrations during dry periods have been associated with reduced flow velocity, organic matter accumulation, and limited reaeration capacity. These similarities indicate that the water quality issues observed in the Upcycle Park River are characteristic of highly urbanised tropical catchments and support the application of nature-based solutions such as constructed wetlands and bioretention systems for river rehabilitation.

Similar trends have been reported in other Malaysian urban river rehabilitation studies. Kamaruddin et al. (2020) reported elevated nutrient and heavy metal concentrations in Sungai Juru due to industrial and urban discharges. Studies in the Klang River Basin also showed increased suspended solids and nutrient loading during rainfall events caused by stormwater runoff. The present findings are consistent with these observations, indicating that urban runoff remains a dominant pollution source affecting river systems in highly urbanised catchments. Consequently, nature-based solutions such as constructed wetlands and bioretention systems have been widely recommended due to their effectiveness in reducing nutrient loading, suspended solids and organic pollutants.

5.4 Proposed Solutions for Water Quality Improvement

The rehabilitation of the Upcycle Park River must take into account its hydrological connectivity with Tasik Bandar Perda, since the river collects discharge from the retention pond before discharging downstream. This hydraulic link implies that circumstances inside the lake, such as nutrient buildup, sediment deposition, and pollution imports from nearby metropolitan areas, have a direct impact on the river's

water quality. Retention ponds are intended to reduce peak flows and trap sediments; but, without suitable treatment systems, they may also function as pollution storage zones, accumulating nutrients and organic matter over time [6].

Constructed wetland systems can be strategically placed near the retention pond's outlet. These systems use vegetation, designed substrates, and microbial processes to eliminate suspended particles, nutrients, and organic pollutants via sedimentation, filtration, adsorption, and biological absorption. By polishing the discharge from the retention pond, built wetlands can greatly enhance downstream water quality while simultaneously increasing habitat complexity and ecological resilience.

In addition, along approximately 1.80 km of the Sungai Juru corridor, bioretention systems are proposed on both riverbanks to intercept uncontrolled surface runoff before it enters the drainage network. Layered soil media, vegetation, and filtration beds remove sediments and nutrients before water enters the lake system, following MSMA (2012) guidelines [4]. Gross Pollutant Traps (GPT) installed at key drainage points capture coarse debris and floating waste, reducing treatment load on downstream systems [3,8,11].

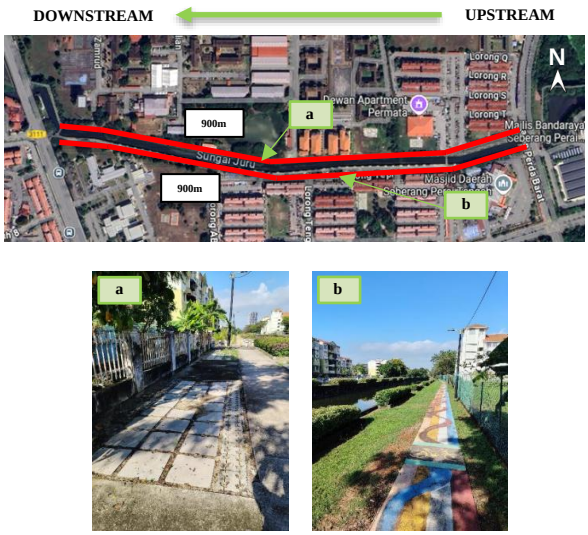

Fig. 9 – Proposed bioretention system locations along both riverbanks

A specialized Monitoring Station with automated samplers and in-situ sensors monitors crucial parameters including water temperature, dissolved oxygen (DO), pH, ammoniacal nitrogen (NH_3-N), electrical conductivity and periodic water samples for lab analysis. [13]

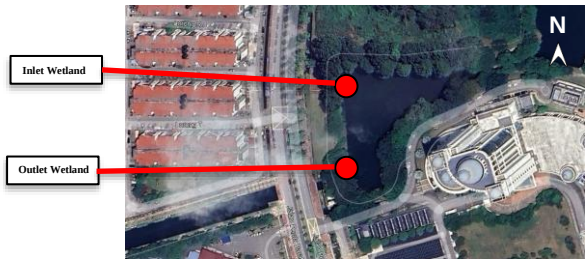

Fig. 10 – Proposed water quality monitoring stations at the inlet and outlet of the constructed wetland system

The location has the potential to become a migratory bird sanctuary, and its ecological significance makes it a excellent match for a future UNESCO ecohydrology demonstration site. Such a location could become a key attraction in Seberang Perai, promoting sustainable tourism and strengthening community-based activities.

6. Conclusion

The DOE Water Quality Index (WQI) and the National Lake Water Quality Standards (NLWQS) Category D were used in this study to evaluate the water quality of the Upcycle Park River in Seberang Perai Upcycle Park. According to the results, the river is classified as being between Class III and Class IV, indicating a polluted state with significant seasonal change. Low flow and restricted dilution throughout the dry season led to persistently low levels of dissolved oxygen (DO), a sign of oxygen stress and pollutant buildup, as well as elevated amounts of NH_3-N, total phosphorus (TP), and BOD. On the other hand, because of stormwater runoff from nearby cities, turbidity, suspended particles, nutrients, and certain heavy metals were elevated during the rainy season. Rainfall increased pollution from non-point sources while also enhancing dilution effects. To improve the water quality, the implementation of a Constructed Wetland System, Bioretension System, Gross Pollutant Trap (GPT), and Monitoring Station is recommended. These measures are expected to enhance ecological integrity and improve the long-term sustainability of the river system.

Acknowledgement

The authors wish to express their sincere thanks to Majlis Bandaraya Seberang Perai (MBSP) and MICRON Memory Malaysia Sdn. Bhd. for their involvement and support in this project.

References

[1] Aziz, A. and Ismail, H. (2021) 'Regulatory frameworks for industrial pollution control: Strengthening enforcement mechanisms in Malaysia', Asian Journal of Environmental Governance, 15(2), pp. 145–162.

[2] Department of Environment Malaysia (2020) Malaysia Water Quality Index (WQI) Classification. Putrajaya: DOE Malaysia.

[3] Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., et al. (2015) 'Sustainable stormwater management: A critical perspective', Environmental Science & Technology, 49(19), pp. 10763–10772.

[4] Gurnell, A.M., Bertoldi, W. and Tockner, K. (2016) 'The role of vegetation in riverbank stabilization and ecological enhancement', Journal of Environmental Management, 172, pp. 35–45.

[5] Ho, C.M., Lim, J.S. and Tan, P.Y. (2022) 'Governance frameworks for sustainable river management: A comparative analysis of Malaysia, Japan, and Germany', Journal of Environmental Policy, 33(1), pp. 55–72.

[6] Kamaruddin, N., Hassan, A. and Lim, C. (2020) 'Industrial wastewater discharge and heavy metal contamination in Sungai Juru', Environmental Toxicology and Water Quality, 18(3), pp. 225–240.

[7] Majlis Bandaraya Seberang Perai (2025) Upcycle Park: A Sustainability Landmark in Seberang Perai. Penang: MBSP Publications.

[8] Rahim, A.R., Zainal, M. and Othman, S. (2022) 'Watershed management strategies for sustainable river rehabilitation in Malaysia', Journal of Sustainable Water Resources, 34(1), pp. 205–220.

[9] Singh, R., Ahmad, T. and Kumar, P. (2019) 'Nature-based solutions for urban water pollution: The role of constructed wetlands and biofiltration systems', International Journal of Environmental Solutions, 21(2), pp. 150–168.

[10] Zainal, M.R., Hassan, S. and Noor, A. (2018) 'Integrated watershed management strategies: A Malaysian perspective', Journal of Water Resources Management, 32(5), pp. 783–799.

[11] Zhang, Y., Li, X. and Wang, J. (2021) 'Emerging contaminants in urban river systems: Microplastics, pharmaceuticals, and personal care products', Environmental Pollution Review, 33(5), pp. 530–548.

[12] Urban Agenda Platform (2018) Upcycle Park at Bandar Perda, Bukit Mertajam: A Community-Driven Sustainability Project.

[13] Zulkifli, R., Wahab, J. and Noor, S. (2020) 'Community-based river rehabilitation: Public participation in water quality monitoring', Asian Journal of Environmental Sustainability, 14(3), pp. 67–82..