International Journal of Sustainable Energy and Environmental Research
2024 Vol. 13, No. 1, pp. 25-35
ISSN(e): 2306-6253
ISSN(p): 2312-5764
DOI: 10.18488/13.v13i1.3682

A preliminary study of direct observation and selected water quality monitoring in Putrajaya Lake: the status between October-December 2022

Nur'ain Azhar[1]
Chee Kong Yap[2+]
Rosimah Nulit[3]
Hishamuddin Omar[4]
Wan Mohd Syazwan[5]
Chee Seng Leow[6]

[1,2,3,4,5]*Department of Biology, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.*
[1]*Email: yapckong@hotmail.com*
[2]*Email: yapchee@upm.edu.my*
[3]*Email: rosimahn@upm.edu.my*
[4]*Email: hishamspirulina@gmail.com*
[5]*Email: mhdsyazwan@upm.edu.my*
[6]*Humanology Sdn Bhd, 73-3 Amber Business Plaza, Jalan Jelawat 1, 56000 Kuala Lumpur, Malaysia.*
[6]*Email: cwyap1968@yahoo.com*


(+ Corresponding author)

Article History
Received: 27 December 2023
Revised: 12 February 2024
Accepted: 15 March 2024
Published: 20 March 2024

Keywords
Monitoring
Putrajaya Lake
Rainfall
Sustainability
Water quality.

ABSTRACT

The objective of this study was to provide the status of water quality based on a direct observation and selected water quality parameters (nitrite, ammonia, and pH) monitoring study between October-December 2022. Between October and November 2022, the levels of the above three surface water quality parameters were measured in 6 different sites throughout Putrajaya Lake. Observational pictures of the sites were also taken, and water samples were collected. In addition to the above observation and water quality monitoring study, the rainfall data was collected from 17th October 2022 to 11th December 2022, cited from the official website of Public Infobanjir (https://publicinfobanjir.water.gov.my/?lang=en) at stations Sg. Anak Gajah and Sg. Limau Manis, was also used to understand the possible correlation. However, further studies are needed. It was found that the water quality status was in good condition, making Putrajaya Lake a safe and suitable lake for aquatic life and recreational activities between October -December 2022. This could be due to the sustainable practices and rainwater harvesting system already implemented at Putrajaya Lake. Putrajaya Lake's water quality monitoring and sustainability practices were well implemented. However, regular maintenance to provide acute monitoring of water quality data at Putrajaya Lakes is necessary in the future.

Contribution/Originality: This direct observation and three selected surface water quality monitoring are part of our continuous monitoring study to check and know the water quality status on the specified dates (between October and December 2022) by direct observation and selected water quality parameter measurement. This simple monitoring is not regularly reported in the literature even though it is practically researched. The present findings could trigger more such types of monitoring studies to be conducted and to be published in the literature.

1. INTRODUCTION

Putrajaya, or the full name of the Federal Territory of Putrajaya, is a smart capital in a park located 25 kilometres south of Kuala Lumpur. It is a futuristic city that houses the administrative centre of the Federal Government (Moser, 2010). It is the 3rd Federal Territory in Malaysia. Putrajaya, with a 4.3 per cent annual population growth rate for 2021–2022, saw the fastest population growth (Department of Statistics Malaysia, 2022). The Putrajaya Lake is an artificial water body designed and managed with an emphasis on achieving the best water quality and ecosystem services in urban development. The lake has an area of 600 hectares and is 12% of the entire area of Putrajaya. The position of the Lake and Wetland project from the north to south, east and west of the Putrajaya area, bordering 15

of the total 20 precincts in Putrajaya except Precincts 7, 9, 14, 15 and 20. The 400-hectare Putrajaya Lake is indeed planned to be the pinnacle of Putrajaya's glory, where residents and tourists can gather together and enjoy the beautiful scenery and perform various sports and recreational activities (Majizat, Ahmad, Noordin, & Sharip, 2016).

The ecohydrological management approach implemented is also in line with the concept of "Integrated Lake Basin Management" which was pioneered by the "International Lake Environment Committee" (ILEC) based at Shiga University, Japan. After a decade, the Putrajaya Lake and Wetland remain magnificent, remaining in the global network of UNESCO ecohydrological sites (Daud, Pereira, & Mokhtar, 2011). The management of Putrajaya Corporation is determined to ensure that this recognition remains forever. Hence, there is a need for daily and periodic maintenance, data observation, health index assessment, and improvement management actions covering all aspects of integrated management of lakes and wetlands implemented systematically and effectively to empower the achievement of output and outcomes in line with long-term development objectives. The objective of this study was to provide the status of water quality based on a direct observation and selected three surface water quality parameters (nitrite, ammonia, and pH) monitoring study between October and December 2022.

2. METHODOLOGY

2.1. Study Site

Putrajaya Lake has 400 hectares of water. The lake has 23.5 million cubic metres of water and 3–14 metres of depth. The lake is designed for fishing, water sports, relaxation, and transit. The lake and its foreshores are Putrajaya's most popular informal recreation area as a waterfront city (Daud et al., 2011). Table 1 shows the features of Putrajaya Lake. Between October and November 2022, the levels of ammonia, nitrite and pH in the surface water samples were collected from 6 different sampling sites throughout Putrajaya Lake, as shown in Figure 1 and Table 2. The three parameters were measured based on the manual of analytical protocols as described by API ® Freshwater Master Test Kit. In addition, the colour of the water samples was also recorded. Photos of the sites were taken using the iPhone XS max camera.

Table 1. Principal features of Putrajaya Lake.

Catchments area	Water level	Surface area	Storage volume	Average depth	Average catchments inflow	Average retention time
50.90 km²	21.00 m	400 ha (4 km²)	23.50 mil. m³	6.60 m	200 million litres	132 days

Source: Perbadanan Putrajaya (2019).

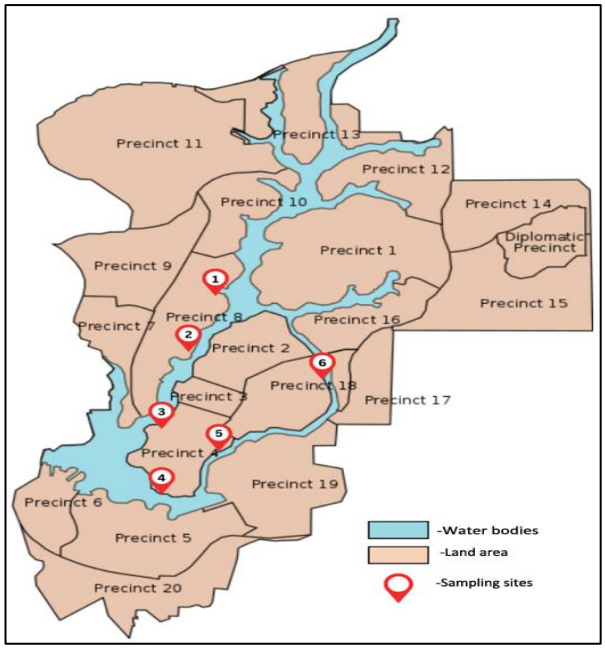

Figure 1. Sampling sites throughout Putrajaya Lake.

Table 2. Precincts and coordinates of each sampling site.

Sampling site	Precinct	Coordinates
1	8	2.94015°N, 101.68839°E
2	8	2.92440°N, 101.67980°E
3	4	2.91288°N, 101.67790°E
4	4	2.90411°N, 101.67721°E
5	4	2.90754°N, 101.68466°E
6	18	2.91644°N, 101.69955°E

Other than that, the rainfall data was also recorded in Putrajaya, in which two stations were selected that were located in Sungai Anak Gajah and Sungai Limau Manis. Rainfall data was collected from 17th October 2022 till 11th December 2022 from the official website of Public Infobanjir (https://publicinfobanjir.water.gov.my/?lang=en).

3. RESULTS

A total of 6 sites were visited and water samples were collected in those sites Figure 2. All of the sites were either utilised for recreational activities or fishing.

+ **Sampling site 1.** Located in Kelab Tasik Putrajaya.

Sampling site 2. Located in Ayer @ 8.

Sampling site 3. Located in Anjung Floria.

Sampling site 4. Located at picnic site in Presint 4.

Sampling site 5. Located in Taman Rekreasi dan Cabaran Presint 4.

Sampling site 6. Located in residential area, Presint 18.

Figure 2. Sampling sites and water samples collected in 6 different sites at Putrajaya Lake (All photos were taken by Nur'ain Azhar)

For site 1, located in Kelab Tasik Putrajaya, the main activities conducted there were kayaking and boating activities. No vegetation was seen in the surrounding area, but fishes were quite abundant due to visitors feeding them regularly. As for site 2, located in Ayer @ 8, the water was quite murky, and no vegetation was seen. This can be attributed to the fact that the area is surrounded by restaurants and people going there for recreational activities such as cycling. In site 3, located in Anjung Floria, there was quite a lot of sedimentation seen in the lake as the area was mostly utilized for the Festival "Floria," a floral and gardening show. In sampling site 4, located at a picnic site in Presint, the water was clear and stagnant. The area was relatively quiet, with minimal human disturbances. Next is site 5, located in Taman Rekreasi dan Cabaran Presint 4. The area was near a bridge where most visitors were seen resting and walking. The water was relatively clean and calm. Last but not least, in site 6, a residential area in 18, the water was slightly murky as the residents often feed the fish in the lakes.

Recreational activities like swimming, boating, and fishing, may harm ecosystem functioning or biodiversity (Venohr et al., 2018). For instance, fishing for fun promotes the spread of invasive species (Lewin, Arlinghaus, & Mehner, 2006). Recreational disturbances can potentially harm wildlife or habitat quality, for instance by generating bird flight reactions (Frid & Dill, 2002). In fact, escape behaviour may significantly impact fitness and population size. In a similar manner, boating can reduce vegetation cover and may result in trampling effects that compact the soil and reduce vegetation cover (Andrés-Abellán et al., 2005). Particularly, disturbance-sensitive taxa are impacted by human presence along the water's edge, which may also impact ecosystem functioning and conditions, such as water quality (Schafft, Wegner, Meyer, Wolter, & Arlinghaus, 2021).

Table 3. Mean levels of ammonia, nitrite and pH of the surface water samples collected from the six sampling sites.

Site	Ammonia (ppm)	Nitrite (ppm)	pH
1	0.25	0.00	7.0
2	0.50	0.00	6.8
3	0.00	0.00	7.0
4	0.25	0.00	7.0
5	0.00	0.00	7.0
6	0.00	0.00	7.0

From Table 3, it can be seen that the nitrite was valued at 0ppm and the ammonia ranged from 0.25-0.50ppm. As for the pH, they recorded 6.8-7.0 pH recorded from the sites. Based on observational analysis, it can be seen that the water sedimentation and colour were the most obvious in site 6.

From the average rainfall intensity in Putrajaya was highest during November 11-13, 2022, at 71.5-84.5 (mm). October saw substantially less rain than November and December. Malaysia's weather is shaped by the Southwest Monsoon, which begins in late May and lasts through September, and the Northeast Monsoon, which lasts from November to March (Malaysian Meteorology Department, 2022). The Northeast Monsoon, from China and the North Pacific, generates more rain than the Southwest. Southwest monsoons originate in Australia's deserts. In March and October, the monsoons alternate (Suhaila, Deni, Zin, & Jemain, 2010). This is evident from Figure 3 data.

From Figure 3, it can be seen that the water parameters were varying based on the months. This can also be related with the rainfall data from October to December. The low levels of ammonia (0.25-0.50ppm) recorded from the present study can be highly attributed to the high amount of rainfall in November. Quirós (2003) stated that the release of sewage water and runoff from agricultural areas treated with pesticides and fertilisers could result in the introduction of inorganic nutrients into the soil, enhancing lake productivity and, consequently, the development of algal blooms like crops. However, in the case of Putrajaya Lake, such anthropogenic activities could be ruled out.

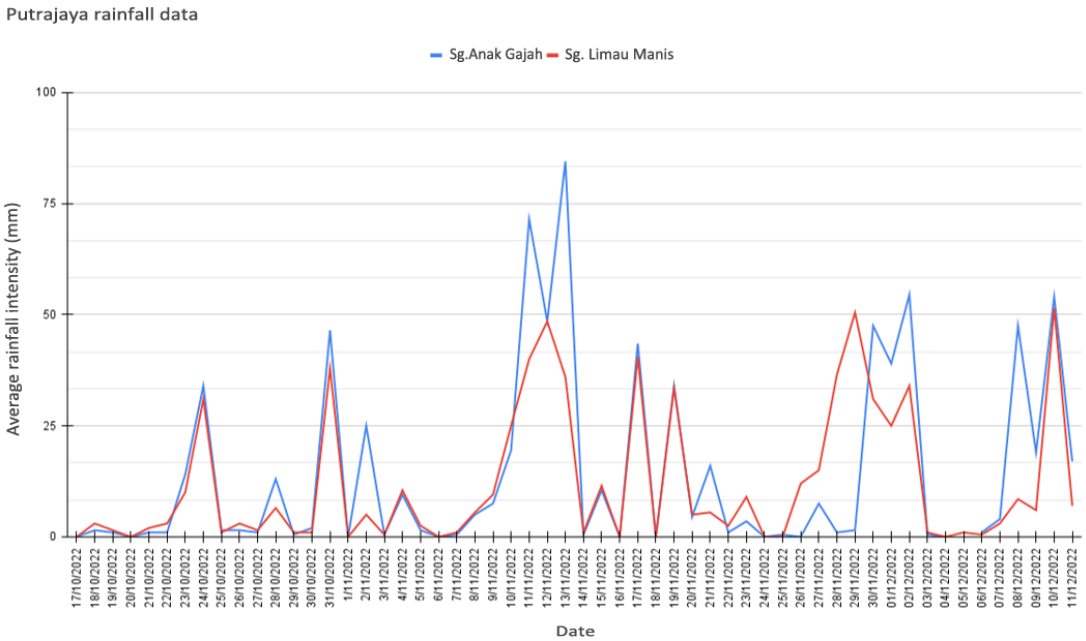

Figure 3. Putrajaya rainfall (mm) data from 17th October 2022 till 11th December 2022.

The pH levels (6.8-7.0) was found to be relative neutral with almost no evidence of acidity Other biological activity rates are likewise impacted by pH. Adding carbonates and bicarbonates raises CO2 levels, affecting lake production (Bailey, Nelson, & Fonteno, 2000).

The water quality index (WQI) from 2001 to 2020 was also obtained from previous reports by Perbadanan Putrajaya. From Figure 4, it can be seen that the WQI for Putrajaya Lake throughout the years ranged from 88.0-94.5 WQI. The values were recorded to be above 76.5, placed at WQI Class I and II. These classes are safe for recreational use, and aquatic species and require no treatment according to National Water Quality Standards for Malaysia (Department of Environment, 2005). This shows that the lake in Putrajaya is safe and clean to use.

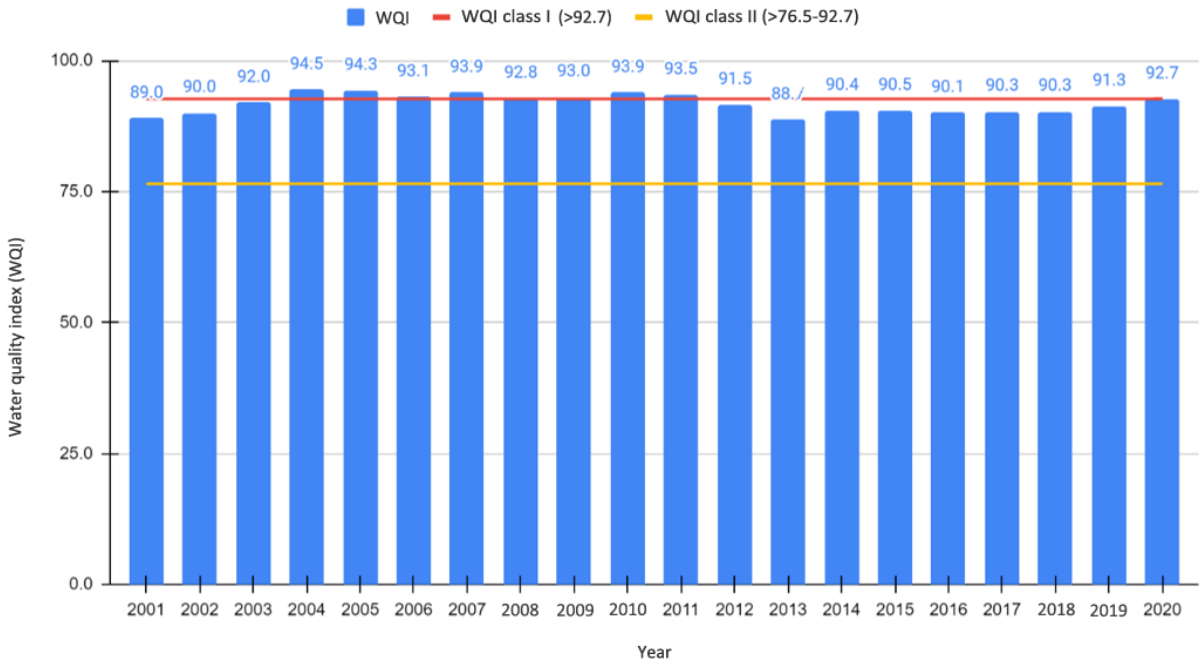

Figure 4. Water quality index of Putrajaya Lake from 2001-2020.

4. DISCUSSION

4.1. Importance of Putrajaya Lake

In the environmental aspect, the Putra Lake stores vast volumes of water and release it when there is a shortage; a proper lake can lessen the effects of floods and droughts. Additionally, the lake helps replenish groundwater, improve water quality downstream watercourses, and maintain local biodiversity and ecosystems. We all stand to gain from this valuable resource when the ecological jigsaw pieces of a lake fit together and the lake can function as it should. Various animals can be found around the lake thanks to migratory birds, appealing wetlands, and emergent flora.

They may provide a municipality with raw drinking water and are revered by many for their traditional and historical values. Most of the lakes in Putrajaya are man-made and were built so that people might engage in recreational and educational activities. Lake Recreational Park is used as a place for water sports recreation. In addition, a man-made lake was built in the middle of Putrajaya to serve as a recreational area for boating, fishing, and other water sports. Additionally, it has a cooling impact on the city and creates revenue when it becomes a well-liked tourist destination.

4.2. Water Quality Monitoring

Perbadanan Putrajaya has created extremely particular, in-depth procedures and management rules to meet the standards. The Putrajaya Lake Use Master Plan and Environmental Management Guidelines are included in the lake management guidelines, which also consider the overall management scope of lakes and wetlands. Every section of the guidelines outlines very specific lake management issues, including the policy for lake quality management, the lake management strategy, administrative responsibilities, relevant data regarding the lake system, the lake monitoring programme, the operation programme, and research and development (Salamat, 2007).

One initiative taken is the Putrajaya Corporation Supervisory Control and Data Acquisition (PJC SCADA) Line Lake Water Quality Monitoring System at Putrajaya Lake, as shown in Figure 5. This device can provide an early detection of pollutants and assist in investigating the pollution sources. The system will provide an early warning system, water physio-chemical parameters, pollutants trending, continuously capturing the effluent discharge, and assess the effectiveness of management strategies and mitigating measures (Alam Sekitar Malaysia Sdn Bhd, 2019).

Figure 5. Putrajaya corporation supervisory control and data acquisition (PJC SCADA) Line lake water quality monitoring system at Putrajaya Lake (Photos was taken by Nur'ain Azhar).

4.3. Sustainability Practices and Rainwater Harvesting

Water stress is believed to increase globally in 2050 due to climate change (Gosling & Arnell, 2016). Additionally, some nations have already experienced water shortages, particularly for drinkable water. Strategies for water conservation must be targeted when water availability becomes scarcer. This effort integrates environmental psychology and environmental engineering to support sustainable development. The cornerstone of environmental management is in line of the three United Nations' Sustainable Development Goals name #6 (clean water and sanitation), #11 (Sustainable cities and communities), and #14 (Life below water).

Putrajaya Lake plays a crucial role in sustainable practices and rainwater harvesting. The lake serves as a key water source for the city and contributes to the overall water management system. Rainwater harvesting is an essential component of sustainable practices in Putrajaya Lake. By collecting and storing rainwater, the city reduces its reliance on traditional water sources such as rivers and reservoirs. This practice helps to conserve water resources and maintain the ecological balance of the surrounding area. Additionally, the collected rainwater can be used for various purposes such as irrigation, gardening, and cleaning. Furthermore, the reuse of greywater and the treatment of wastewater for reuse are also identified as potential water sources in Putrajaya Lake (Zyl & Jooste, 2020). These practices further contribute to water conservation and reduce the overall water stress in the region. The implementation of these sustainability practices and rainwater harvesting in Putrajaya Lake reflects the city's commitment to environmental stewardship and resilience in the face of climate change and water scarcity challenges (Lani, Yusop, & Syafiuddin, 2018; Nizam, Hanafiah, Mokhtar, & Jalal, 2021; Zabidi, Goh, Chang, Chan, & Zakaria, 2020).

Currently, lakes and reservoirs are important sources of freshwater. They are essential to human society to provide drinking water, provide food (via fisheries, aquaculture, and irrigation of agricultural fields), provide recreation, produce energy (through hydropower dams), treat wastewater, and control floods and droughts. Numerous lakes and reservoirs have experienced serious degeneration due to the (mainly recent) heavy exploitation. While eutrophication remains the principal problem for many lakes and ponds globally, physical (habitat) degradation has recently gained significant importance. Along with the ongoing risks posed by anthropogenic activities like urbanisation, industry, aquaculture, and changes to watercourses, climate change and newly emerging contaminants like microplastics and antimicrobial resistance can pose a significant threat to the long-term viability of lakes and reservoirs (Ho & Goethals, 2019). Therefore, lakes' social (community engagement), economy (tourism and recreation) and environmental (environmental conservation) factors should be taken seriously to maintain a more sustainable lake community. This would involve and create eco-friendly infrastructure and renewable energy generation at Putrajaya (Figure 6).

Rainwater harvesting (RWH) collects and stores rainwater instead of letting it drain off, according to Pacey and Cullis (1986). Rainwater is directed from a roof-like surface to a percolating tank, cistern, deep pit, aquifer, or reservoir to replenish groundwater. Dew and fog can be collected with nets or other tools. Rainwater harvesting is promoted in all Putrajaya Corporation planning, development, and post-construction phases. The 600 hectare Putrajaya Lake and Wetlands, a massive detention pond with an estimated 24.5 million cubic metres of storage, has been developed in phases from 1997 as a rainwater collecting project (Majizat, Sahat, Ibrahim, & Mohd, 2009).

The government mandated the installation of a rainwater collection and utilization system, which is only applicable to large structures like factories, schools, and large bungalows in March 2006 (Hafizi Md Lani, Yusop, & Syafiuddin, 2018). Putrajaya Corporation has increased its efforts in the RWH implementation strategy since receiving the instruction in March 2006. Installing rainwater collecting systems in residential areas, corporate buildings, lakes, and wetlands is one example of its utilization in Putrajaya. In Putrajaya, rainwater harvesting improves water quality in other ways, such as by preventing waste, debris, chemical agents, and other pollutants from getting into Putrajaya Lake (Mohammed, Noor, & Ghazali, 2007).

Figure 6. A conceptual model of sustainable practice in Putrajaya Lake.

5. CONCLUSION

In conclusion, this study shows that the rainfall patterns in Putrajaya could be related to nitrite, ammonia, and pH of the surface water samples collected from Putrajaya Lake. However, further studies are needed. The good water quality conditions supported by the observational study showed that Putrajaya Lake was a safe and suitable lake for aquatic life and recreational activities between October-December 2022.

This could be due to the sustainable practices and rainwater harvesting system already implemented at Putrajaya Lake. This showed that Putrajaya Lake' water quality monitoring and sustainability practices were well implemented.

However, regular maintenance to provide acute monitoring water quality data at Putrajaya Lake is necessary in the future.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Conceptualization, C.K.Y.; methodology, C.K.Y. and N.A.; software, W.M.S.; validation, C.K.Y., N.A. and R.N.; formal analysis, C.K.Y. and N.A.; investigation, C.K.Y., N.A. and H.O.; resources, H.O., W.M.S., C.S.L. and T.W.C.; data curation, N.A., H.O., W.M.S. and C.S.L.; writing—original draft preparation, N.A.; writing—review and editing, C.K.Y. R.N., H.O., W.M.S., C.S.L. and T.W.C.; visualization, R.N. and W.M.S.; supervision, C.K.Y.; project administration, C.K.Y. and R.N. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Alam Sekitar Malaysia Sdn Bhd. (2019). *The evolution of environmental monitoring*. Retrieved from https://smart.putrajaya.my/event/dipec/2019/source/download/talk29.pdf. [Accessed 25-1-2024]

Andrés-Abellán, M., Alamo, J. B. D., Landete-Castillejos, T., López-Serrano, F. R., García-Morote, F. A., & Cerro-Barja, A. D. (2005). Impacts of visitors on soil and vegetation of the recreational area "Birth of the Mundo River" (Castilla-La Mancha, Spain). *Environmental Monitoring and Assessment, 101*(1), 55-67.

Bailey, D. A., Nelson, P. V., & Fonteno, W. C. (2000). *Substrates pH and water quality*. Raleigh: North Carolina Sate University.

Daud, M. Z. B., Pereira, J. J., & Mokhtar, M. B. (2011). Putrajaya North watershed, Malaysia-challenges of water quality management Putrajaya, Malaysia. *Sains Malaysiana, 40*(8), 831-840.

Department of Environment. (2005). National Water Quality Standards for Malaysia. pp. 70-72.

Department of Statistics Malaysia. (2022). *Current population estimates, Malaysia*. Retrieved from https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155&bul_id=dTZXanV6UUdyUEQ0SHNWOVhpSXNMUT09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09#:~:text=Putrajaya%20recorded%20the%20lowest%20population,1.0%20million%20mark%20in%202021. [Accessed 25-1-2024]

Frid, A., & Dill, L. (2002). Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology, 6*(1), 1-16.

Gosling, S. N., & Arnell, N. W. (2016). A global assessment of the impact of climate change on water scarcity. *Climatic Change, 134*(3), 371-385.

Hafizi Md Lani, N., Yusop, Z., & Syafiuddin, A. (2018). A review of rainwater harvesting in Malaysia: Prospects and challenges. *Water, 10*(4), 506. https://doi.org/10.3390/w10040506

Ho, L. T., & Goethals, P. L. (2019). Opportunities and challenges for the sustainability of Lakes and reservoirs in relation to the sustainable development goals (SDGs). *Water, 11*(07), 1462. https://doi.org/10.3390/w11071462

Lani, N. H. M., Yusop, Z., & Syafiuddin, A. (2018). A review of rainwater harvesting in Malaysia: Prospects and challenges. *Water, 10*(4), 506-506. https://doi.org/10.3390/w10040506

Lewin, W.-C., Arlinghaus, R., & Mehner, T. (2006). Documented and potential biological impacts of recreational fishing: Insights for management and conservation. *Reviews in Fisheries Science, 14*(4), 305-367. https://doi.org/10.1080/10641260600886455

Majizat, A., Ahmad, B., Noordin, N., & Sharip, Z. (2016). Adopting an integrated catchment-based management approach for Putrajaya Lake and Wetlands. *International Journal of Water, 10*(4), 343-358. https://doi.org/10.1504/IJW.2016.079701

Majizat, A. H., Sahat, R., Ibrahim, M., & Mohd, F. (2009). *Policy and implementation of rainwater harvesting in Putrajaya Malaysia*. Retrieved from https://silo.tips/download/sustainable-water-management-a-case-study-of-putrajaya-malaysia

Malaysian Meteorology Department. (2022). *Weather phenomena- monsoon*. Retrieved from https://www.met.gov.my/en/pendidikan/fenomena-cuaca/#Monsoon

Mohammed, T. A., Noor, M. J. M. M., & Ghazali, A. H. (2007). *Study on potential uses of rainwater harvesting in Urban areas*. Paper presented at the Proceedings of the Colloquium on Rainwater Utilisation, Putrajaya, Malaysia, 19&20 April 2007.

Moser, S. (2010). Putrajaya: Malaysia's new federal administrative capital. *Cities*, *27*(4), 285-297. https://doi.org/10.1016/j.cities.2009.11.002

Nizam, N. U. M., Hanafiah, M. M., Mokhtar, M., & Jalal, N. A. (2021). Water quality of rooftop rainwater harvesting system (MyRAWAS). *IOP Conference Series: Earth and Environmental Science*, *880*(1), 012039-012039. https://doi.org/10.1088/1755-1315/880/1/012039

Pacey, A., & Cullis, A. (1986). *Rainwater harvesting the collection of rainfall and runoff in rural areas*. London: Intermediate Technology Publ.

Perbadanan Putrajaya. (2019). *Lakes and wetlands*. Retrieved from https://www.ppj.gov.my/en/second-page/tasik-dan-wetland. [Accessed 25-1-2024]

Quirós, R. (2003). The relationship between nitrate and ammonia concentrations in the Pelagic zone of Lakes. *Limnetica*, *22*(1-2), 37-50.

Salamat, Z. (2007). *Putrajaya Lake: Sustainable management of created Wetland*. Paper presented at the Colloquium on Lakes & Reservoir Management: Status and Issues.

Schafft, M., Wegner, B., Meyer, N., Wolter, C., & Arlinghaus, R. (2021). Ecological impacts of water-based recreational activities on freshwater ecosystems: A global meta-analysis. *Proceedings of the Royal Society B*, *288*(1959), 20211623. https://doi.org/10.1098/rspb.2021.1623

Suhaila, J., Deni, S. M., Zin, W. Z. W., & Jemain, A. A. (2010). Trends in peninsular Malaysia rainfall data during the Southwest monsoon and Northeast monsoon seasons: 1975–2004. *Sains Malaysiana*, *39*(4), 533-542.

Venohr, M., Langhans, S. D., Peters, O., Hölker, F., Arlinghaus, R., Mitchell, L., & Wolter, C. (2018). The underestimated dynamics and impacts of water-based recreational activities on freshwater ecosystems. *Environmental Reviews*, *26*(2), 199-213. https://doi.org/10.1139/er-2017-0024

Zabidi, H. A., Goh, H. W., Chang, C. K., Chan, N. W., & Zakaria, N. A. (2020). A review of roof and pond rainwater harvesting systems for water security: The design, performance and way forward. *Water*, *12*(11), 3163-3163. https://doi.org/10.3390/w12113163

Zyl, A. V., & Jooste, J. L. (2020). Retaining and recycling water to address water scarcity in the City of Cape Town. https://doi.org/10.1080/0376835x.2020.1801387