**Machine learning methods for better water quality prediction (79 Citations) 2019**

Ahmed, A. N., Othman, F. B., Afan, H. A., Ibrahim, R. K., Fai, C. M., Hossain, M. S., ... & Elshafie, A. (2019). Machine learning methods for better water quality prediction. *Journal of Hydrology*, *578*, 124084.

Water quality parameters are of considerable significance in any aquatic system analysis.

Traditional modelling methodologies involve large amount of unknown datasets and is a time-consuming process.

AI can identify non-linear and complex relationships.

Johor river basin major degradation because of developmental and human activities

Water Quality prediction model for better water resource management is of critical importance.

Adaptive Neuro-Fuzzy Inference System (ANFIS), Radial Basis Function Neural Networks (RBF-ANN), and Multi-Layer Perceptron Neural Networks (MLP-ANN) were studied with historical data of water quality parameters. WQ parameters of focus were Ammoniacal Nitrogen (AN), suspended solid (SS) and pH. There were twelve input parameters and data from 2009-2010 were used.

This study also assesses significance of every input parameter partitioning NN’s connection weight and also assesses most effectual input using a single and a combination of parameters.

(Wavelet de-noising technique) WDT-ANFIS outperformed other models with R^2 greater than or equal to 0.9 in predicting both pH and SS. Model could also capture temporal patterns in WQ

**Predicting Urban Water Quality with Ubiquitous Data (39 citations) 2016**

Liu, Y., Liang, Y., Liu, S., Rosenblum, D. S., & Zheng, Y. (2016). Predicting urban water quality with ubiquitous data. *arXiv preprint arXiv:1610.09462*.

Novel data-driven approach to forecast WQ by fusing multiple sources of urban data

Urban water quality is of great importance to our daily lives and prediction of wq is important to control water pollution and human health.

Water quality in urban spaces vary non-linearly and depend on multiple factors such as meteorology, water usage patterns and land uses.  
This study forecasts WQ from monitoring stations from WQ data and water hydraulic data by implementing a data-driven approach. It also fuses multiple datasets from different domains into a unified learning model

**Participatory research to monitor lakewater pollution 2021 (0 )**

Aronoff, R., Dussuet, A., Erismann, R., Erismann, S., Patiny, L., & Vivar‐Rios, C. (2021). Participatory research to monitor lake water pollution. *Ecological Solutions and Evidence*, *2*(3), e12094.

Used E.coli bioindicator for detecting raw sewage contamination. Results found microbial burdens occurred during music festivals

Contamination of lake water causes human health issues in lakes used for recreational activities like swimming. Monitoring water quality is crucial (through microbial abundance) to avoid risks to health along shoreline recreational areas

Study confirms Power of participatory research: dedicated people on a budget can do meaningful environmental monitoring.  
  
Open science can bridge academic, public(governmental) and commercial worlds. Partocopatory research and community science are more preferable over

Each site was tested for pH, temp, DO and turbidity

\*\*Algal blooms producing toxins or depleting oxygen

**Continuous Monitoring of Water Quality Using Portable and Low-Cost Approaches (49 citations) 2013**

Tuna, G., Arkoc, O., & Gulez, K. (2013). Continuous monitoring of water quality using portable and low-cost approaches. *International Journal of Distributed Sensor Networks*, *9*(6), 249598.

Measuring water quality at drinking water reservoir require collecting large number of samples.  
Wireless sensor network based monitoring system was used for monitoring

WQ is one of the main factors to control health and state of disease in people and animals.

Anthropogenic inputs such as industrial and municipal wastewater discharge largely determine surface WQ.  
Lakes and rivers are main drinking water sources

Sustainable use of water quality resources require surface water assessment monitoring prigrams.

Water Framework Directive(WFD), major reference to guide efforts to attain sustainable aquatic environment consitsts of guidelines defining the categories f parameters required: DO, pH, EC, temp, turb and nitrate are main params to determine WQ as stated by WFD 7 US EPA

Main problem in surface WQ monitoring is complexity associated with collecting LARGE number of samples.

Fixed monitoring systems require high initial start-up cost but provide real-time data.  
Portable devices does not provide real-time WQ data

**Youtube Videos**

Cyanobacteria/blue-green algae -> find what is in the lake   
Oxygen in the atmosphere from Great Oxygenation Event, about a couple of billion years ago, was created by cyanobacteria. Cyanobacteria -> microalgae . Seaweed- macro algae

Toxic algae kills marine animals and harmful to human health. They grow in warm temperature, need plenty of light and nutrients. Calm waters. Nutrients act like fertilizers (just like plants) Blooms are usually because of human’s effect on the ecology  
Nutrient sources that cause the blooms are varied so hard to pin point exactly which nutrient is causing the bloom (is it agricultural/septic systems that are not controlled well, is it runoff from lawn/grass fertilizers. Pinpointing exact trigger is difficult

HAB (Harmful Algal blooms)

Algal blooms can be seen near shoreline. Some are harmless but others can release toxins that are harmful for people and animals. Algal blooms prevent the use of water resources either for drinking or for other purposes/ recreation

**Water Quality Characterization of Varsity Lake, University of Malaya, Kuala Lumpur, Malaysia 2010 (39)**

Ashraf, M. A., Maah, M. J., & Yusoff, I. (2010). Water quality characterization of varsity lake, University of Malaya, Kuala Lumpur, Malaysia. *E-Journal of Chemistry*, *7*(S1), S245-S254.

Increased levels of nitrogen in the water, combined with phosphorus, can cause excessive plant and algal growth that depletes oxygen levels, possibly to lethal levels.

Some algal blooms also produce toxins that can affect aquatic life or humans that consume them

**Eco-Heart Index as a tool for community-based water quality monitoring and assessment 2018 (11)**

Sakai, N., Mohamad, Z. F., Nasaruddin, A., Abd Kadir, S. N., Salleh, M. S. A. M., & Sulaiman, A. H. (2018). Eco-Heart Index as a tool for community-based water quality monitoring and assessment. *Ecological Indicators*, *91*, 38-46.

The collection of hydrological data often requires advanced technology and a high cost,

This study uses 6 water quality parameters: pH, heavy metals, chemical oxygen demand(?), transparency, ammonia nitrogen and dissolved oxygen.

Water quality monitoring was done using Pact Test and LAQUAtwin. Pact test for pH, COD, NH3-N and heavy metals. works by colorizing a specific parameter by dipping a plastic tube containing a coloring agent into a sample to quantify its concentration by comparison with a color indicator.

LAQUAtwin is a handheld meter that can check a water quality parameter within a minute by simply dipping its sensor into a sample.

community-based monitoring enabling the community to participate in citizen science.

A transparency tube was used for the analysis of turbidity. It can be easily prepared with a transparent tubing and a secchi disk attached to its bottom. The transparency is recorded by a maximum height of a water sample poured into the tubing where the secchi disk is visible from the top. **Although the result is more or less affected by observers**, and the measurement range is generally narrower than a turbidity meter, this method is much simpler and more economical than those used in turbidity and TSS.

A portable DO meter was used for the DO measurement. Although it incurs a high initial cost, proper usage and maintenance allows for accurate and long-lasting measurements with minimal maintenance cost.

The eco-heart index is strongly correlated with WQI and is more informative and attractive to drive policies.

Langat River basin in Malaysia- pollution detected in mid-stream and downstream areas, particularly in populated and land development areas

Malaysia is no exception and water pollution is one of the most serious water resource management

issues in the country. According to the Department of Environment Malaysia (DOE), 36.6% of rivers in Malaysia were classified as slightly polluted, and 5.2% of rivers were classified as

polluted

[**A Study on Water Quality Status of Varsity Lake and Pantai River, Anak Air Batu River in UM Kuala Lumpur, Malaysia and Classify it based on (WQI) Malaysia**](https://eqa.unibo.it/article/view/7967) **2018 (1)**

GAFRI, H. G. F. (2018). A Study on Water Quality Status of Varsity Lake and Pantai River, Anak Air Batu River in UM Kuala Lumpur, Malaysia and Classify it based on (WQI) Malaysia. *EQA-International Journal of Environmental Quality*, *29*, 51-65.

turbidity, nutrient, nitrate, ammonia, and phosphate DO, COD, SS, BOD, NH3-N, and PH, *E.coli* and Total *Coliform*

The agro-industry, which consumes 70% of the water resources in Malaysia, severely pollutes the rivers from point sources and non-point sources.

According to Department of Environment Malaysia (DOE, 2012), there are three parameters of contamination that significantly affect river quality; BOD, SS, and NH3-N (Ammoniacal Nitrogen).

**Automated Water Quality Survey and Evaluation Using an IoT Platform with Mobile Sensor Nodes 2017 (31)**

IoT platform measured Temp, pH, DO, EC, ORP. The developed platform provided a cost-effective, fast, deployable, and easily maintainable solution for the high-resolution ~~spatiotemporal~~ telemoitoring of surface water.

The data collected in this approach can benefit aquatic environmental monitoring in various applications such as the survey of an unknown area for collecting useful knowledge to establish an environmental model, the design of a sensor deployment strategy for long-duration monitoring, an analysis of microaquatic environmental changes, and so on.

### [Autonomous in situ measurements of noncontaminant water quality indicators and sample collection with a UAV](https://www.mdpi.com/433254) 2019 (12)

Koparan, C., Koc, A. B., Privette, C. V., & Sawyer, C. B. (2019). Autonomous in situ measurements of noncontaminant water quality indicators and sample collection with a UAV. *Water*, *11*(3), 604.

UAV assisted autonomous water sampling system (UASS) developed in this study was equipped with three water sampling cartridges and sensor nodes for in-situ measurements of water quality at different depths.

The system allows rapid sampling from difficult to access water bodies (inaccessible and dangerous water bodies) with relatively low costs and can operate without intense training for practitioners. It lowers operational cost and is useful for monitoring water reservoirs, lakes, rivers, and ponds periodically/ after natural disasters.

Parameters: Temp, EC, pH, DO.

### [Environmental reviews and case studies: bringing unmanned aerial systems closer to the environment](https://www.cambridge.org/core/journals/environmental-practice/article/environmental-reviews-and-case-studies-bringing-unmanned-aerial-systems-closer-to-the-environment/880BBCDB9AF3491A0A779B7B119659A8). 2015 (15)

Detweiler, C., Ore, J. P., Anthony, D., Elbaum, S., Burgin, A., & Lorenz, A. (2015). Environmental reviews and case studies: bringing unmanned aerial systems closer to the environment. *Environmental Practice*, *17*(3), 188-200.

The spatiotemporal resolution of these datasets will enable policymakers to better measure the impact of policies

### [Can drones be used to conduct water sampling in aquatic environments? A review](https://www.sciencedirect.com/science/article/pii/S0048969719312446?casa_token=xLTnH95fn_EAAAAA:Cp0w9PIUZB9y3gzeyA28ePDVAqkCIjcOkoPEKO_nJ4IQqNYeRHMC57PgxuxSJthkYQqwIHLIIXk) 2019 (25)

Lally, H. T., O'Connor, I., Jensen, O. P., & Graham, C. T. (2019). Can drones be used to conduct water sampling in aquatic environments? A review. *Science of the total environment*, *670*, 569-575.

Research stated that 330ml of water samples is insufficient for sampling (the volume collected by drones)

Further advancements in drone platforms and mounted sensor technology will increase their potential application in environmental monitoring of terrestrial and aquatic ecosystems by allowing rapid access to environmental data (

### [In situ water quality measurements using an unmanned aerial vehicle (UAV) system](https://www.mdpi.com/269190) 2018 (58)

Koparan, C., Koc, A. B., Privette, C. V., & Sawyer, C. B. (2018). In situ water quality measurements using an unmanned aerial vehicle (UAV) system. *Water*, *10*(3), 264.

Temp, EC, DO and pH are the most common indicators of impairment of water quality in river, ponds and lakes etc.

A custom-built hexacopter was equipped with an open-source electronic sensors platform to measure the temperature, electrical conductivity (EC), dissolved oxygen (DO), and pH of water.

Point source of pollutants in streams include: drainage channels, industrial plant outlets, wastewater treatment facilities, confined animal feeding operations, agricultural runoff.

Non-point source include: Impervious surfaces such as roadways, rooftops, parking lots, sidewalks accumulate pollutants and convey them directly to lakes, rivers and estuaries.

The growth of dense algal blooms causes discoloration in water bodies, and can potentially result in damaging fluctuations of dissolved oxygen.

Among algal blooms, blue-green algae have the genetic potential to produce toxins which are harmful to humans and animals.

Traditionally, to detect harmful changes in the waterbodies, agencies responsible for water quality monitoring collect water samples periodically and analyze them in the laboratory. These methods are costly, labor-intensive, and the measurements are not representative of the neighboring waterbodies

nutrient leaching from farm fields or pasture land into surface water has the potential to cause algal blooms.

water sampling after a storm event, regular water sampling is necessary to identify the entry points of pollutants into surface water.

Remote sensing has the advantages of making measurements on a larger scale and over a long time period. This allows the managers to observe the changes in water quality in coastal waters, estuaries, lakes, and reservoirs

over time.

In addition, lakes with cyanobacteria (blue-green algae) blooms may pose risks to humans during collection of water samples

data from traditional point sampling is not sufficient for identifying spatial or temporal variations in water quality, nor for forecasting for large waterbodies. The integration of satellite remote sensing data with in situ measurements is necessary for making accurate and timely management decisions.

**Water quality monitoring strategies — A review and future perspectives 2016 (186)  
*(a good source for checking tables for literature review and technologies)***

Behmel, S., Damour, M., Ludwig, R., & Rodriguez, M. J. (2016). Water quality monitoring strategies—A review and future perspectives. *Science of the Total Environment*, *571*, 1312-1329.

Water Quality Monitoring Programs (WQMP)

No holistic solution exists to cover all steps of WQMPs because of the differences in regulatory requirements,water quality standards, geographical and geological differences, land-use variations, and other site specificities.

It is also necessary to tap into local knowledge and to identify the knowledge needs of all the stakeholders through participative approaches based on future research should focus on developing such participative approaches

WQMPs which can be done with IoT enabled water quality allows timely information production for the stakeholders

Reliable assessment of water quality through water quality monitoring programs (WQMPs) is crucial for decision-makers to understand, interpret and use this information in support of their management activities aiming at protecting the resource.

Intelligent decision support systems are needed in support of watershed managers

continuous quality control and assessment, data storage, adequate and timely information production for the stakeholders and changes in governance. In other words, a tool that can rapidly assist the watershed manager in every aspect of a WQMP: stakeholder implication, scientiﬁc requirements, administrative requirements, and governance.

Allwater stakeholders, defined as policy-makers, city planners, water conservation organizations, industry sectors, universities and the general public, should be part of the process in order to take joint decisions and actions to protect the resource for economic, social, environmental and public health reasons.

We believe that a computerized decision support system (DSS) is necessary to provide the support watershed managers' needs in the

process of planning and optimizing WQMPs.

### [Design of amphibious vehicle for unmanned mission in water quality monitoring using internet of things](https://www.mdpi.com/347178), 2018 (28)

Esakki, B., Ganesan, S., Mathiyazhagan, S., Ramasubramanian, K., Gnanasekaran, B., Son, B., ... & Choi, J. S. (2018). Design of amphibious vehicle for unmanned mission in water quality monitoring using internet of things. *Sensors*, *18*(10), 3318.

Parameters measured: turbidity, DO, pH, EC \*\*Uses DF robot sensors. Hardware consumed 7.58W of power and the data transmission took 11ms

Measurement of water quality is usually performed with the aid of boats, which is labor-intensive and costly. remote sensing methods of water quality assessment is time-consuming and needs lot of investment . Traditionally, water body agencies are collecting the water samples manually and in a periodic manner, which is cumbersome . Few of the lakes, rivers, ponds, and reservoirs may not have access to collect water samples with boats and they might be surrounded with shrubs and bushes

### [Development of unmanned surface vehicle for water quality monitoring and measurement](https://ieeexplore.ieee.org/abstract/document/8394316/) 2018 (12)

Yang, T. H., Hsiung, S. H., Kuo, C. H., Tsai, Y. D., Peng, K. C., Hsieh, Y. C., ... & Kuo, C. (2018, April). Development of unmanned surface vehicle for water quality monitoring and measurement. In *2018 IEEE International Conference on Applied System Invention (ICASI)* (pp. 566-569). IEEE.

Traditional methods are accurate but time-consuming and hence it leads to a slow response in response to pollution/ natural disaster. developed UAV which carries a mobile water quality sensor to perform real-time scan of water qualities

### [Telesupervised remote surface water quality sensing](https://ieeexplore.ieee.org/abstract/document/5446668/) 2010 , (19)

Podnar, G., Dolan, J. M., Low, K. H., & Elfes, A. (2010, March). Telesupervised remote surface water quality sensing. In *2010 IEEE Aerospace Conference* (pp. 1-9). IEEE.

Parameters: temp, pH and DO

This study presented a fleet of autonomous robot sensor boats (RSB) developed for lake and river fresh water quality assessment. It used a multi-sensor water sonde (expensive) to asses water quality in small recreational lakes and carried tests over 3 months in clear vs hair algae-laden and before and after heavy rain. It is important because runoff water after heavy rainfall might be polluted with man-made pollutants like fertilizer and waste materials

In 2005, the National Research Council completed its study, “Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania.” [2] This report focused on the need for a comprehensive watershed-based approach in the region, and specifically called for increased data collection and modeling of critical water resources.

incidents of significant accidental and intentional contamination continue. Industrial waste dumping, storage tank ruptures, acid mine drainage, combined sewer overflows, and train derailments (Figure 1) all contribute to crisis situations of critical surface water systems.

Remote supervision, the human observer is not exposed to the contamination as would be the case when testing water quality or gathering samples from a regular boat.

Water resources in a region are critical to economic growth as well as to quality of life. Water quality data give us insight into the suitability of the water for aquatic life and for human use;

### [Design of online data measurement and automatic sampling system for continuous water quality monitoring](https://ieeexplore.ieee.org/abstract/document/7237850/) 2015 (24)

Wiranto, G., Mambu, G. A., Hermida, I. D. P., & Widodo, S. (2015, August). Design of online data measurement and automatic sampling system for continuous water quality monitoring. In *2015 IEEE International Conference on Mechatronics and Automation (ICMA)* (pp. 2331-2335). IEEE.

NOT CONNECTED TO THE INTERNET

Parameters: DO, pH, temperature

### Over the past decade, online water quality monitoring has been widely used in many countries known to having serious issues related to environmental pollution [1-3]. In such countries, accurate, reliable and real time water quality parameter data are required by environmental authorities to ensure that industrial and domestic pollutants are kept below

### [Experimental evaluation of an autonomous surface vehicle for water quality and greenhouse gas emission monitoring](https://ieeexplore.ieee.org/abstract/document/5509187/) 2010 (47)

Dunbabin, M., & Grinham, A. (2010, May). Experimental evaluation of an autonomous surface vehicle for water quality and greenhouse gas emission monitoring. In *2010 IEEE International Conference on Robotics and Automation* (pp. 5268-5274). IEEE.

solar powered catamaran is capable of collecting various water quality measurements by moving a sensor payload up and down the water column

This study evaluated experimentally an ASV capable of navigating complex inland water reservoirs and measuring a range of water quality properties.

The role of the ASV is to autonomously navigate and continuously collect WQ information and relay back to the shore in real-time

the data collected by the ASV complemented with existing manual monitoring campaigns with improved spatial and temporal monitoring of water storage.

The continuous monitoring of these nodes enables early detection of events such as algal blooms

### [Smart technology for water quality control: Feedback about use of water quality sensors](https://ieeexplore.ieee.org/abstract/document/8125060/) 2017, (2)

Saab, C., Shahrour, I., & Chehade, F. H. (2017, September). Smart technology for water quality control: Feedback about use of water quality sensors. In *2017 Sensors Networks Smart and Emerging Technologies (SENSET)* (pp. 1-4). IEEE.

### [Smart technology for water quality control: Feedback about use of water quality sensors](https://ieeexplore.ieee.org/abstract/document/8125060/) 2017 (2)

### Saab, C., Shahrour, I., & Chehade, F. H. (2017, September). Smart technology for water quality control: Feedback about use of water quality sensors. In *2017 Sensors Networks Smart and Emerging Technologies (SENSET)* (pp. 1-4). IEEE.

Total Organic Carbon, Dissolved Organic Carbon, pH, free chlorine, conductivity

The traditional methods frequently used, are based on laboratory analyses and take several days.  To prevent earlier water quality degradation, real-time monitoring is required.

For early detection of contamination in water distribution networks distributed sensor networks were used which performed well compared to laboratory tests

**Water warrior Accounts (No citation/Not an article) Simple guide to lake restoration**

Water Warrior’s (WW) experience in Varsity lake of UM. In urban setting lakes are either artificial (for recreation) or leftover from mining industry. WW committed to long term management and they use Integrated Lake Basin Management (ILBM) approach.

ILBM for sustainable management of lakes and it integrates six pillars of institutions, participation, policies, technology, information and finance.

Sources of pollution identified: Point source (pipe, drains or sewerage lines) & Non-point source (rainfall which carries runoff water with human-made pollutant such as fertilizer and trash)

WW check water quality to assess the current state of the lake ad set target for lake restoration (research, fixing and life)

Lab tests give accurate measurements whereas lowcost monitoring kit provide a baseline although the measurements are not reliable and has low accuracy. To get accurate data, monitoring tests need to be done in-situ for params such as DO and temp and ex-situ (at the lab).

Six standard parameters they measure are: Ammoniacal Nitrogen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, pH and Total Suspended Solids according to National Water Quality standards for Malaysia [<http://www.wepa-db.net/policies/law/malaysia/eq_surface.htm>]

Main challenges faced is Eutrophication where the water turn green or brown or worse, bluish- called algal bloom. Algal bloom occurs mainly die to nutrient loading from fertilizers and human/animal waste. To prevent eutrophication, Nutrient inlet needs to be controlled, aeration is needed which is provide by aerator or recreational activities such as kayaking or to introduce zooplankton such as daphnia that feeds on the algae. Extreme cases of aquatic weeds or wetland plant such as water cabbage and water hyacinth grows abundantly and can be overcome by controlling nutrient loading through manual harvesting or inrofucing new species which feeds on the plants such as grass carp.

Citizent scientist are involves in restoration work, giving them a sense of belonging to the area and the data collected from water quality monitoring is plotted in the Eco-heart index (heart shaped graph). The results of the monitoring needs to be archived and stored ni the form of online mapping. The platform serves as information hub and aids in the decision-making process by stakeholders and also makes the community more aware

### [Development of in situ sensors for chlorophyll concentration measurement](https://www.hindawi.com/journals/js/2015/903509/) 2015 (32)

Zeng, L., & Li, D. (2015). Development of in situ sensors for chlorophyll concentration measurement. *Journal of Sensors*, *2015*.

Chlorophyll measurement is an effective method to quantify and analyze freshwater and seawater phytoplankton in situ. Chlorophyll is measured using fluorescence, which is the red light re-emitted by chlorophyll molecules when excited by light source. It is a noninvasive method for analyzing photosynthetic energy conversion of higher plants, algae and bacteria.

Fluorometry has long been used to study phytoplankton in natural aquatic environments. Typical applications include estimation of primary productivity and phytoplankton distribution [4–6], understanding photosynthetic characteristics and taxonomic discrimination, and assessment of nutrient status and toxins sensitivity.

Chlorophyll lab measurement require sample transportation and the sampling procedure is typically time consuming and samples have the potential to change during transportation.

Chlorophyll concentration and harmful algal blooms over very large areas can be detected by remote monitoring of ocean color. However small variarions of chl cannot be identified by such means. IN SITU fluorometers offer continuous measurement of chl concentrations and do not require pretreatment or large sample volume. In situ measurement is simple, nondestructive, selective, sensitive and rapid. HOWEVER, fluorescence is weak, unstable and easily influenced by environment.

Both in-vivo(within the living) and in situ fluorescence measurement’s accuracy and stability are influenced by the environment in which the phytoplankton lives. Value of chla fluorescence is affected by yellow substances, chromophoric dissolved organic matter and biofouling (buildup of microorganisms on the structure, for eg. Ship’s hull).

Calibration is critical step for sensor application. Chl fluorescence is susceptible to variation caused by operating environment, biofouling, instrument design, sensor drift and calibration rigor.

### NAHRM (2014) Blueprint for Lake and Reservoir Research

Lakes supply 98% of Malaysia’s 98% of total national water use.

16 reservoirs contributing to 11% of total Energy through Hydroelectric

More than 12 reservoirs used for flood mitiagation

More than 10 used for irrigation, fishing and aquaculture

Preserved biodiversity

Recreation and tourism. Heritage ~~and patrimony~~: Older lakes support community and cultural values

Main threats faced is from Eutrophication and the sources are:

Unsustainable logging activities and land clearance -> Sendiments, nutrients-> Eutrophication & Sedimentation

Urbanization and inadequate treatment facilities-> Sewage and effluent discharges-> eutrophication/pollution

Unsustainable agriculture/farming practices-> Nutrients, pesticides -> Eutrophication and pollution

Environmental monitoring needed for to assess the current status or conditions of the environment, current trends in environmental parameters, detecting pollutions/cotnaminants and suitability for beneficial/intended usage.

Lake water monitoring: crucial for informed decision making and management, enables better understanding of lake water quality state and catchment conditions.

Monitoring is lacking in many stagnant water bodies and no specific agency monitoring lake water quality.

Need for lake water monitoring : Lentic water characteristics-> long retention time-slow ecosystem changes (gradual and invisible). Complex response dynamics-unpredictable and uncontrollable. System won’t recover fully (or Regime shift [transition between a turbid state dominated by algae and a clear state with macrophyte dominance] may set it—Hysteresis, source Nakamura, M 2009) .

National Lake Water Quality and Criteria and Standards (NLWQS): Physicochemical measurements for Aethetic and Nutrient measurements for Eutrophication and Sedimentation control. NLWQS promote preservation of human health and ecosystem

Water monitoring links to sustainable management of lakes:

Monitoring lake water quality and ecosystem health helps to develop integrated lake basin management plan and continually assess governance improvement. Links to SDG6.

Lake environmental monitoring aid in the management and protection of water bodies

### [Formulating specific water quality criteria for lakes: A Malaysian perspective](https://books.google.com/books?hl=en&lr=&id=GMOQDwAAQBAJ&oi=fnd&pg=PA293&dq=Formulating+Specific+Water+Quality+Criteria+for+Lakes:+A+Malaysian+Perspective&ots=d-BkRY1Wcb&sig=rSTH6P7gVnoZHzOGV4IEFvowob8) 2017 (4) (contains table of national water quality criteria for all params and classified into groups)

Sharip, Z., & Suratman, S. (2017). Formulating specific water quality criteria for lakes: A Malaysian perspective. *Water Quality; Tutu, H., Ed.; IntechOpen: Rijeka, Croatia*, 293-313.

Monitoring water quality of inland water bodies such as lakes, reservoirs and ponds throughout Malaysia is important to ensure that these water bodies can be managed sustainably for their ecosystem functioning and services

Eutrophication of inland water is a prevalent issue in Malaysia, one which threatens the

functioning of lake and reservoir ecosystems throughout the country. A preliminary study of the status of lake eutrophication reported that more than 60% of the 90 lakes being studied were nutrient rich [1] with a few of them especially the urban lakes experiencing algal blooms, which affect human uses of the water, such as recreation and aesthetic values, while other lakes faced macrophyte infestation problems

At present, there are only two national standards of water quality in Malaysia, namely the National Water Quality Standards (NWQS) and the National Drinking Water Quality Standards (NDWQS), which were developed for the purpose of river and drinking water protection. Currently, lake monitoring efforts have focused on using the NWQS due to the unavailability of specific water quality criteria for lakes.

the majority of the lakes studied were categorized as suitable for recreational purposes, although, they did experience eutrophication

Microbial hazards are considered to be the primary concern by the WHO as they have the largest impact on health in terms of waterborne disease, especially when compared to chemical hazards which are usually associated with long‐term exposure.

From the Naional Lake Water Quality Criteria table, some relevant water quality params and their classes:

*Physico-chemical* (temp, pH, DO, EC, Turbidity)

*Nutrient* (Ammoniacal Nitrogen, Nitrite-N, Nitrate-N, Total Nitrogen (TN), Total Phosphorus (TP), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chlorophyll-a

*Heavy Metals* (arsenic, …etc)

*Organics or Pesticides*

### [In situ measurements of phytoplankton fluorescence using low cost electronics](https://www.mdpi.com/53054) 2013 (86)

Leeuw, T., Boss, E. S., & Wright, D. L. (2013). In situ measurements of phytoplankton fluorescence using low cost electronics. *Sensors*, *13*(6), 7872-7883.

Chlorophyll *a* fluorometry has long been used as a method to study phytoplankton in the ocean. *In situ* fluorometry is used frequently in oceanography to provide depth-resolved estimates of phytoplankton biomass. However, the high price of commercially manufactured *in situ* fluorometers has made them unavailable to some individuals and institutions.

In oceanography, monitoring the distribution of phytoplankton (microscopic algae) in the water column is vital to understanding many large-scale physical and biological processes.

Historically, fluorescence was primarily measured *in vitro*.

However, aerial methods can only measure chlorophyll *a* at the ocean surface during daylight hours. High resolution measurements of chlorophyll *a* concentration at depth require the use of submersible *in situ* fluorometers. This makes *in situ* fluorometers an essential tool for 21st century oceanography.

### National overview: the status of lakes eutrophication in Malaysia 2007 (10)

Sharip, Z., & Yusop, Z. (2007, August). National overview: the status of lakes eutrophication in Malaysia. In *Colloquium on Lakes and Reservoir Management: Status and Issues* (pp. 2-3). Putrajaya: NAHRIM.

Proposed environmental management strategies for lake conservation including eutrophication control, ecosystem conservation include 5 broad categories with one including REGULAR water quality monitoring program.

Chemical monitoring: Most monitoring and management programmes for eutrophication control have focused on phosphorus management, typically Total Phosphorus (TP) and soluble phosphorus. Soluble form is unstable and must be immediately analyzed. Chemical monitoring is difficult in lake/reservoir environment. Association of phosphorus with fine-grained sediment requires estimate of the amount of phosphorus which is transported with the sediment load to the lake and with sediment that has been deposited in the bottom of the lake (? You need to collect from the bottom?)

Bio-assessment: Different levels of eutrophication tend to be associated with different types of quantities of algal species. Most common biological parameter in monitoring regime for eutrophication is chl-a which is a measure of primary production

Estimation techniques: a particular problem in many countries is the lack of necessary and reliable data to estimate the nature and scope of eutrophication problem. Data is necessary to develop nutrient loading and to make management decisions on the type of source controls that are likely to make significant improvement in the level of eutrophication. Estimation techniques must include both point sources and nonpoint source of pollution (can use meterological data coupled with sensor systems)

### National Lake water quality criteria and standards by NAHRIM (not a paper)

Koko National Lake Water Quality Criteria and Standards (NLWQS) for Malaysian lake water use is essentially a user needs specification of the quality of water required for different protection uses. The criteria is useful to make informed judgement on the fitness of the lake water for recreational purposes and ecosystem heath for aquatic life diversity protection. NLWQS is applicable to any lake, reservoir, dams, ponds etc.

NLWQS is developed as an information resource for lake managers, operators and owners.

Monitoring guide: Appropriate parameters are selected based on 1. Ease of measurement, 2. Cost of sampling and analysis 3. Availability of equipment and related measurement technologies 4. Relevance to the purpose of lakes.

Parameters were highlighted according to different categories of lakes:

Physical measurements: clarity, DO, temp

Nutrient: phosphorus, nitrogen which indicate trophic state of a lake

Biological/Microbiological: BOD, COD and bacterial content

Heavy Metals

Carlson’s Index is used as an indication for trophic state/ eutrophication level of lakes in Malaysia. Research effort is needed to find suitable values of Carlson’s Index that would suit Malaysian climate and conditions. Parameters used for Carlson’s Index: Chl-a, Phosphorus, Secchi Depth.

Table

Description automatically generated