Geographical Information System (GIS) and Remote Sensing (RS) Applications in Green Port Water Quality Management in Malaysia

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Abstract:-Latest port generation is more adapted to eco-friendly environmental. Thus, port industry is experiencing new challenges as it is subjected to increased pressure for environment protection enforcement. Water quality issues are among the most widely debated topics since they have a significant effect on water resources, biodiversity, and health impacts and well-being. The polluted water from vessels and facilities in the port leaving the water inappropriate for consumption and instigating water-related infections so it must be controlled and monitored regularly. This paper will examine and review the various Geographic Information System (GIS) and Remote Sensing (RS) to identify, mapping and monitor the water quality. One of the water quality managements is by considering the Water Quality Index (WQI). The parameters consist of ammoniacal nitrogen, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total suspended solid (TSS). WQI will show the state of water quality at a station and if pollution happen, RS will detect and then the data can be sent directly to GIS. This technology is advantages in order to help store data and handle water quality data more effectively. GIS and RS provides a way to summarize overall water quality situations in a way that can be clearly communicated to different audiences, can help understand whether overall water quality poses a threat to water resources in port areas. The use of GIS and RS also to demonstrate results in water quality protection and rehabilitation efforts.

Keywords: *Port, Geographical Information System, Remote Sensing, Water Quality Index*

1. Introduction

River pollution and water quality are among the most sensitive concerns because they have a considerable influence on water supplies, biodiversity, and health and well-being (Wan Mohtar et al., 2019). Nonetheless, fat growth in many metropolitan areas, including Malaysia, is accompanied with negative urbanisation consequences, and these human activities have resulted in changes to surface ground cover, which leads to water quality depletion owing to point and non-point source contamination (Pak et al., 2021). Polluted water from all these sources is severely polluting the rivers, rendering it unfit for human consumption and causing water-borne diseases (Gupta & Gupta, 2021).

As a result, authorities' first concern is determining the water quality. Geological, hydrogeological, and geophysical studies, as well as field surveys, are common ways for identifying and clearly defining water. This involves a large amount of effort for operations such as exploration, which is time, money, and resource intensive and required the participation of experts. Modern technologies, such as Geographic Information Systems (GIS) and remote sensing (RS), are, on the other hand, less expensive, more responsive, and more convenient (Shao et al., 2020). Geographic Information System (GIS) will be used for gathering, managing, and analyzing environmental data around the Port area. Due to recent progress in remote sensing analysis, cloud computing and machine learning, the evaluation of remote sensing capability in water quality monitoring and decision-making is essential (Sagan et al., 2020).

2. Review Methodology

The aim of the research is to examine and review the various use of Geographical Information System (GIS) and Remote Sensing (RS) in water quality management. Much research has been completed worldwide utilising GIS and remote sensing for mapping water quality (Demirel et al., 2011; Jeihouni et al., 2018; Oguchi et al., 2000; Rad et al., 2017; Sagan et al., 2020; Taloor et al., 2020). To achieve the goal, the researcher used a systematic strategy, and 22 relevant publications were picked for "water quality management", "Water Quality Index (WQI)', "GIS' and "remote sensing", from Google Scholar, ScienceDirect and SpringerLink. This study will focus on: (1) water quality management; (2) Water Quality Index (WQI); and (3) application of GIS and remote sensing in water quality management.

2.1 Water Quality Management

The consistency of the ambient water has an impact on the health and self-purification potential of riverine ecosystems (VishnuRadhan et al., 2017). Any changes in quality features must be detected immediately in the water quality framework, as stated above, to assure real-time safety. In the United States, monitoring systems are installed on bodies of water so that the water quality can be measured on a monthly or annual basis, depending on the situation. It is critical to guarantee that the water quality is maintained or restored to its pre-treatment or treatment condition. A close check must be kept on it on a regular basis to ensure that it is functioning properly. When comparing the types and amounts of contaminants to be controlled, as well as the performance of pollutants modification procedures, water quality monitoring is quite helpful (Aswin Kumer et al., 2021).

It was also possible to analyse data on water quality using sophisticated environmental techniques such as hierarchical cluster analysis (HCA), discriminant analysis (DA), hierarchical agglomerative cluster analysis (HACA), factor analysis (FA), and principal component analysis (PCA) etc. (Abbas et al., 2009). The use of environmetric techniques will aid in the analysis of large and water quality data sets, as well as the accurate representation of spatial water quality data sets, which will aid in the regulation of water quality and long-term planning (Wan Mohtar et al., 2019).

Water quality management is concerned with all aspects of quality issues associated with water's various useful uses (Shen, 2021). According to Somlyódy (1995), water quality management is a transitional phase between environmental management and water resources management. It draws on hydrology, ecology, chemistry, biology, economics, and engineering, among other sciences and disciplines, to control water quality. As a result, water quality management adds a new dimension to the widely recognised problem of water limitation and pollution. Water should be handled in such a way that its use in one place does not jeopardise its use in another, according to the complaint made in the report. It is completely different from water quantity management, which is the engineering of water resource systems ensure that clean water is supplied to all users and within a certain area (Shen, 2021).

The current situation of water quality data programs in Asia and the Pacific is a major source of worry since it served as the framework for a national strategy plan for water quality management. In most cases, data selection is not quality monitored or ensured, and the data may be unreliable; the data is not easily accessible to users; and the data is neither analysed nor turned into data products that can be used for decision-making in the traditional sense. A significant portion of Asia and the Pacific may be categorised as "weak data," therefore adopting new alternatives in decision-making procedures because of data-poor settings is an important consideration (FAO, 2000).

2.2 Water Quality Index

Management of water quality requires the collection and analysis of large water quality datasets that can be difficult to evaluate and synthesis. A range of tools have been developed to evaluate water quality data; the Water Quality Index (WQI) model is one such tool (Uddin et al., 2021). The expression "water quality assessment" involves the identification of physical, chemical, and biological properties depending on the water use range (Khadr & Elshemy, 2017). WQI is used to measure and publish the water quality and quality of each flow (M. Hameed et al., 2016). WQI is a valuable instrument since it expresses the state of a river as a single numerical value (Nabeel M.Gazzaz et al., 2012). Temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Phosphorous (P), Ammoniacal Nitrogen (NH3-N), oil & grease, and E. coli are the water quality parameters calculated (VishnuRadhan et al., 2017).

Table 1. Water classes and use (National Water Quality Standard, 2021)

Class	Uses
Class I	Conservation of natural environment Water supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Clas IV	Irrigation
Class V	None of the above.

The National Water Quality Standards (NWQS) as in Figure 1 below, a compilation of standards derived from advantageous uses of water in Malaysia, were the key methods used to classify river water quality. The NWQS specified classes I–V, which related to river or river section classification based on highest to the lowest of water quality.

To summarize the water quality data for a given river into simple value, WQI is recommended (Zaki Zainudin, 2010). The WQI most commonly being used Malaysia, also known as the Malaysian Department of Environment-Water Quality Index (DOE-WQI), is an interpretation formula in which a special committee is consulted on parameter selection and weightage each of the parameters (VishnuRadhan et al., 2017). The classification of pollution levels by individual pollutants is in line with the DOE standard, as indicated in Figure 2.

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	- 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1– 3	3 - 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 - 5	1 - 3	< 1
pH	-	> 7	6 - 7	5 - 6	< 5	> 5
Total Suspended Solid	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI	-	< 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	> 31.0

Figure 1. DOE Water Quality Index Classification (Yuk and Shin 2015)

2.3 Geographical Information System (GIS)

A geographic information system (GIS) is a platform for the collection, management, and analysis of geospatial data. The geographic information system (GIS), which is based on geography, incorporates a wide range of outputs. It explores spatial position and arranges layers of information into visualisations by utilising maps and 3D scenes as well as 3D models. GIS's one-of-a-kind capacity to offer additional insights into outcomes, such as scenario, relationships, and patterns, enables users to make better decisions by providing them with more information. Hundreds and thousands of companies in practically every sector utilise geographic information systems (GIS) to develop maps that aid organisations in interacting, analysing, disseminating information, and solving complex problems all over the world. The way that universe works will change because of this. Geographic Information Systems (GIS) work in the following ways:

i. Identify problems
ii. Monitor change
iii. Manage and respond to event
iv. Set priorities
v. Perform forecasting
vi. Recognize and analyses trends

GIS were used to create visually appealing GIS zoning maps for the researched groundwater quality parameters in the Abu Dhabi (Batarseh et al., 2021). The use of geographic information systems (GIS) allows you to compare various distinct types of details. The system may make use of information about humans, such as population statistics, wage levels, and education levels. It may contain information about the surrounding environment, such as the location of streams, the types of vegetation present, and the types of soil present, among other things. It is possible to combine geographic science with methods for interpretation and communication using geographic information systems (GIS). It supports people in reaching a common goal: obtaining actionable knowledge from a wide range of different types of information. Geographic information systems (GIS) are used in four ways: maps, data, analysis, and applications (Esri, 2021). According to previous study, GIS are used to determine the source of water quality contamination caused by urbanisation, which is due to an increase in the consumption of groundwater in areas with limited surface water supplies (Enwright & Hudak, 2009; Fytianos & Christophoridis, 2004; Gopinath et al., 2016; Lee et al., 2003; Nas & Berktay, 2010).

2.4 Remote Sensing (RS)

Remote sensing has been defined as the "science of far observation," which has a central function in the creation of the rural and remote catchment area observation framework. Satellite and airborne imaging sensors are often employed for monitoring catchments since they give 10-100-square-meter information (Fu et al., 2019). Optical remote sensing techniques give quick, time-based, and synoptic information on the status of water quality variables that include no interpretative difficulties linked with the sample, including hydro-physical, biological, and biochemical data. Surface reflection is measured from the water or water with the use of satellite-based remote sensing, leaving radiance from concentration of various water components, such as color dissolved organic matter (CDOM), chlorophyll a (chl a), total suspended matter (TSM), and many more (Chawira et al., 2013). To gather additional information about a watershed, sampling and monitoring must be performed as often as possible. Continuous monitoring overcomes the frequency problem by offering intensive long-term observation, sampling, and data collection.

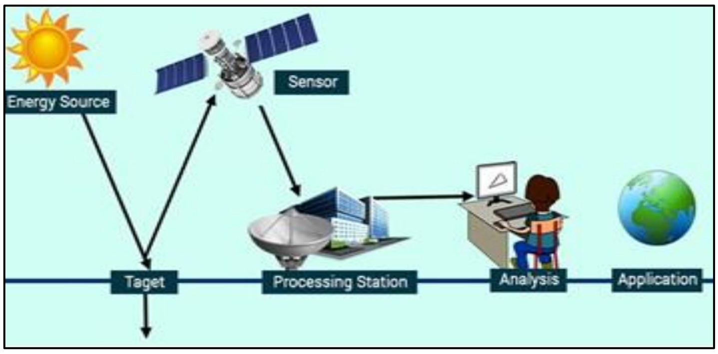

Figure 2. A step-by-step representation of remote sensing process for obtaining outputs (Singh, 2018)

Effective water quality monitoring has a tremendous impact on the quality of the catchment region in general (O'Grady et al., 2021). Figure 3 shows a step-by-step representation of remote sensing process for obtaining outputs. Figure 3 contains a summary of comprehensive list parameters of water quality and its remotely sensed monitoring methods that are linked with them. For the purposes of this analysis, remote sensing platforms such as satellites, aerial, and drones are considered. This type of platform has the capability of housing sensors and technology of imaging.

Sensor	Parameter
Airborne thermal infrared (TIR)	Temperature
MODIS	Dissolved Oxygen
Landsat/MODIS	Total organic carbon
Landsat/SPOT	Total suspended matter
Landsat/MERIS	Turbidity
CHRIS Proba satellite	Conductivity
Landsat	Color dissolved organic matter
Airborne Imaging Spectrometer for Applications (AISA)	Chlorophyll-a
Airborne Scanning Low Frequency Microwave Radiometers (SLFMRs)	Sea surface salinity

Figure 3. Comprehensive list parameters of water quality and its remotely sensed monitoring methods. (O'Grady et al., 2021)

3. Application of GIS And RS for Water Quality Management

According to previous research, GIS and remote sensing have been employed numerous times as applications for water quality management. Data that has been transformed into graphical form is more easily comprehended by all parties involved in the effort to ensure that water quality is always maintained. It is important to maintain constant control over water quality due to the fact that water is a valuable resource for humans. Water sources are widely used in daily life for a variety of purposes, including drinking water, residential and non-residential use, irrigation, and aquaculture, among others. The improved technology of GIS has now made the detection of water quality relatively straightforward (Nazzal et al., 2019).

Additionally, the development and research of remote sensing employing satellite and aerial imagery has been gradually incorporated for monitoring areas that were previously difficult to monitor, resulting in the production of high-resolution data that has become essential for water quality monitoring (Yatim et al., 2016). Detailed review of previous studies is shown in Table 2 below, which includes 22 papers that have been reviewed based on the type of water resources, water quality management, and use of GIS and remote sensing in water quality management.

Table 2. Grouping of Reviewed Studies by Type of Water Resources, Application Fields, and its Source (ScienceDirect and SpringerLink, 2021)

Type of Water Resources	Reviewed Application Fields	Sources
1. River	i. Investigation and modeling of water quality of Göksu River (Cleadnos) in an international protected area by using GIS	(Demirel *et al*., 2011)
	ii. Spatial and temporal risk quotient-based river assessment for water resources management	(Wan Mohtar *et al*., 2019)
	iii. River water quality in the Humber catchment: an introduction using GIS-based mapping and analysis	(Oguchi *et al*., 2000)

2. Groundwater	i.	Assessing groundwater quality for drinking water supply using hybrid fuzzy-GIS-based water quality index	(Verma *et al.*, 2020)
	ii.	Assessment of groundwater quality status by using water quality index (WQI) and geographic information system (GIS) approaches: a case study of the Bokaro district, India	(Verma *et al.*, 2020)
	iii.	Assessing groundwater quality using GIS	
	iv.	GIS-based Evaluation of Water Quality Index of groundwater resources around Tuticorin coastal city, south India	(Babiker *et al.*, 2007) (Selvam *et al.*, 2014)
	v.	Groundwater quality assessment using the Water Quality Index and GIS in Saveh-Nobaran aquifer, Iran	(Sadat-Noori *et al.*, 2014)
	vi.	Groundwater quality assessment using water quality index and GIS technique in Modjo River Basin, central Ethiopia	(Kawo & Karuppannan, 2018)
	vii.	Groundwater quality mapping in urban groundwater using GIS	(Nas & Berktay, 2010)
3. Marine	i.	A GIS-based system for assessing marine water quality around offshore platforms	(Lu *et al.*, 2014)
	ii.	GIS-based health assessment of the marine ecosystem in Laizhou Bay, China	(Song *et al*., 2017)
4. Stormwater	i.	A practical GIS-based hazard assessment framework for water quality in stormwater systems	(Gaafar *et al.*, 2020)
5. Canal	i.	Water quality assessment of lower Jhelum canal in Pakistan by using geographic information system (GIS)	(Bashir *et al.*, 2020)

3.1. River

In research conducted by Demirel et al. (2011), water quality has been contaminated with heavy metals because of agricultural activities and fertilizers. Spatial analysis and integration for water quality mapping in the basin were carried out utilising created thematic maps that were digitised using Map Info GIS software. By assessing the Risk Matrix Approach (RMA), the danger level of Klang River health was analysed and separately plotted using GIS. The created risk hazard mapping has the potential to be one of the most important tools in making important decisions for cost-effective river rehabilitation and restoration. Based on temporal and rigorous research, this representation would aid in the identification of hazardous places.

(Masocha et al. (2017) remotely sensed the catchment condition of total suspended solid levels by the Normalised Difference Vegetation Index (NDVI) and used Landsat 8 as the method to rapidly assess the physical quality of water in inadequate data. It highlights the importance of widely available satellite data for near-real-time physical water quality monitoring at the river catchment level, in resource-constrained places, such as sub-Saharan Africa. The use of GIS mapping techniques aided in the simplification and presentation of a complicated and diverse dataset (Oguchi et al., 2000). The maps have allowed for visual study of spatial interactions between elements. The GIS methodology has effectively proved its capabilities in mapping the wide scale of surface river water quality (Demirel et al., 2011; Oguchi et al., 2000; Wan Mohtar et al., 2019). In RS concept, aircraft-mounted hyperspectral spectrometers were utilised to acquire high spatial and spectral resolution imageries for evaluating optically active water quality features in large rivers in research by Olmanson et al. (2013). Ground-based image sampling supplied calibration data on chlorophyll, suspended particles, and turbidity in conjunction with picture acquisition.

3.2. Groundwater

Water quality index (WQI) model based on geographic information systems (GIS) is used to evaluate groundwater as drinking purposes (Jha et al., 2020; Kawo & Karuppannan, 2018; Sadat-Noori et al., 2014; Verma et al., 2020).

Through Jha et al. (2020) research, Groundwater Quality Index (GQI)-based groundwater quality evaluation utilising Geographical Information System (GIS) has been shown to be a cost-effective approach for monitoring groundwater quality and variability on a broader scale. The typical GQI technique is incapable of dealing with the uncertainties inherent in environmental problem evaluation (Babiker et al., 2007; Jha et al., 2020). GIS-based GQI models based on Fuzzy Logic were created in accordance with World Health Organization (WHO) and Bureau of Indian Standards drinking water guidelines.

According to a research by Selvam et al. (2014), GIS will be used to assess groundwater quality in a complete and integrated manner by using an integrated methodology that integrates the concentration influences of various chemical elements in groundwater aquifers using GIS multi-conditional layering capabilities. For geographical modelling, the inverse distance weighted (IDW) interpolation approach was utilised in research by Kawo & Karuppannan, (2018) and the parameter values were categorised according to WHO (2004) drinking water standards. IDW is a spatial interpolation method or predict values between measurements. Values are measured by determining the inverse of the distance between the location of an observation and the location of the point being estimated. The WQI map created by crunching individual point data and then plotting it in GIS. Shao et al. (2020) have combined RS-GIS for designation and implementation of Fuzzy AHP technique for assessing groundwater well discharges, depth data and step-down drilling of wells at various watershed areas to evaluate diverse groundwater returns.

Nas & Berktay (2010) create thematic maps, and then use ArcGIS Geostatistical Analyst to create a final groundwater quality map. The Kriging method was used in a GIS framework to build spatial distribution maps of chemical characteristics and identify the best linear accurate prediction (Kawo & Karuppannan, 2018; Nas & Berktay, 2010; Sadat-Noori et al., 2014). Site suitability evaluations, evaluating groundwater sensitivity to contamination possibility from nonpoint sources of pollution, maintaining site inventory data, modelling groundwater movement, and combining groundwater quality assessment methods with spatial data to build a spatial visualization are all examples of GIS uses in groundwater research.

3.3. Marine

Marine water quality also needs to be monitored constantly especially from pollution that occurs because of offshore activities. GIS technology is used as a platform to control water quality. Variations in data forms can be used as a method to control water quality. The GIS-based MWQ-FES can be a valuable decision-support approach for monitoring marine water quality. MWQ-FES core components cover the following functions: risk assessment model (including fuzzy synthetic water quality assessment), data entry and input analysis, eutrophication risk and heavy metal risk evaluation, making risk maps with the retrieved data, data storage and management, presenting the database and the risk maps, making risk maps with the collected data, and exporting the findings. In research by Lu et al. (2014), the proposed GIS incorporates eutrophication risk assessment, fuzzy risk calculation, and heavy metal risk evaluation and geographically and visually provides the outcomes in terms of color-coded maps and contour maps indicating danger levels. In conclusion, engineers and decision makers will have better understanding the spatial distribution of water quality problems due to the developed system.

Other than that, Song et al. (2017) using the analytic hierarchy process (AHP) approach, an evaluation index system comprising water quality was created based on monitoring data in Laizhou Bay for two years (2014-2016). This research intends to build an appropriate evaluation index system that is based on a spatial interpolation approach to evaluate the ecosystem health in the Laizhou Bay by using GIS technology in ecosystem health assessment research. ArcGIS has been utilised as a spatialized platform, with spatial outputs analysed to assist the government in improving the regional natural environment. To provide statistics data for marine water quality, this article interpolated each index using inverse distance weighted (IDW), ordinary kriging (OK), and spline function (SP).

3.4. Stormwater

Pollutant fate and transport modelling, stormwater hydrodynamic modelling, concentration mapping, and hazards estimate, and visualisation are all part of the unique GIS-based hazard assessment methodology for stormwater quality presented here. It consists of four distinct stages and three distinct modelling tools, resulting in the "4-stage-3-model" framework. The purpose Gaafar et al. (2020) applying the framework is to provide a realistic, rapid, and stand-alone understanding the entire for pollution levels and water quality hazards that may assist localities in better predicting water quality-related risks of point-source leaks at outlet with no need for resource-intensive models. It defines high and low-risk sections of a stormwater basin using a series of maps, which is particularly useful in identifying regions wherever contaminant discharges are expected to result in large pollution levels or risks at the outflow. Pollution level in the maps depict expected concentrations through an outlet linked with point-source pollution happening anywhere in the stormwater system upstream.

As example, contaminant concentration value of 1.0 mg/L at a given place on the map indicates that a pollutant discharge there would result in a max concentration of 1.0 mg/L at the system outlet. It will not show the actual pollutant concentration at the specified site because it would have been higher than 1.0 mg/L at the start. Instead of shows the value of concentration, the hazard score on the map shown as a percentage from 0 to 100 percent. Such danger maps may also be generalised to diverse water systems and expanded to numerous chemical compounds and contamination source types. These effective and efficient techniques will aid and accelerate stormwater quality control.

Next, the Inverse Distance Weighted (IDW) and Bayesian Kriging Model (BKM) modules are the focus of this study (Nas & Berktay, 2010). With excellent prediction accuracy, the two approaches are frequently used for geostatistical analysis, including soil, air, and water quality mapping.

3.5. Canal

Bashir et al. (2020) analyse spatial distribution map with estimated water quality in physicochemical and biological parameter in canal by using GIS to interpret the suitability of canal for irrigation purpose. An interpolation method called IDW was used to create a thematic layer. At the sample location, a portable GPS device was employed as a tool to aid read data immediately for incorporation in GIS. Water quality index (WQI) is a simple and practical method for expressing several water quality indicators in a single aggregated value and corresponding scale. Yousaf et al. (2021) have implemented RS and GIS as an independent monitoring system for agricultural water adequacy. Landsat-8 and MODIS to estimate the water deficit in crops almost in real time. The results of crop water deficits might be useful for irrigation managers to adjust the rotation plan of canals in almost real-time depending on crop health and growth.

3.6. Lake

RS is an effective instrument to monitor water quality indexes such as chlorophyll_a, total suspended matter and turbidity (Cao et al., 2018; Dlamini et al., 2016; Rostom et al., 2017). Medium Resolution Imaging Spectrometry (MERIS) is used to simultaneously detect several measures of water quality, to ensure that changes are observed in the short term and spatial outcomes that may be utilised for water management and policy makers to monitor water systems (Chawira et al., 2013).

Dlamini et al. (2016) used Moderate Resolution Imaging Spectroradiometer (MODIS) and Cao et al. (2018) using Modified Discrete Binary Particle Swarm Optimization-Partial Least Square (MDBPSO-PLS) which can provide realistic information on chl-a, TSM and turbidity distributions. MDBPSO-PLS is a water quality recovery model that combines the smart algorithm (MDBPSO) with the algorithm Partial Least Squares (PLS). PLS is a multivariate regression model that can be utilised between 400 and 900 nm for water quality recovery with visible and near infrared bands. The PLS sensitivity spectrum is determined using an MDBPSO method for water quality recovery and may reduce the overfit probability of PLS modelling and increase the recovery accuracy. Zhou & Zhao (2011) also consider RS to monitoring the lake by supplying HJ-1A/1B CCD data to reflect water quality problems and to produce division and classification of water quality, lake eutrophication assessment and water pollution assessment, as well as to make it convenient for experts to make further decisions. RS also helps to dynamically monitor water quality to detect changes in lake information on time. Hyperspectral Remote Sensing has the capability to collect detailed information about contamination quickly and cheaply. This study contains the possibility of evaluating heavy metal water contamination in Mariut Lake and projecting water pollution models based on spectral properties and data from the laboratory (Rostom et al., 2017).

4. Conclusion

As conclusion, the aim of this review is to bring to the light GIS and remote sensing applications for water quality improvement and management as a way of improving sustainability with an emphasis on Malaysian green port. GIS and remote sensing are important in the development of water quality database in the Port area.

The existence of a database system can help management to monitor and update the information. The typical structure of GIS mapping for water quality management is determined by the data collected and will generate in systematic way to the production of the information, analytical and graphic which interact between software and humans. Geographic Information System (GIS) can be applied using current technologies that will help store data and handle water quality data more effectively. Data management facilities are now at the fingertips thanks to the use of GIS. Remote sensing gives high spatial and temporal water quality data. It facilitates the assessment of environmental issues and associated health hazards by analysing water quality changes and the identification of contaminants. Various remote sensing projects provide historical information for investigations of water quality trends and the possible consequences on water quality of land use and land coverage. The fact that remote sensing data are available in real time enables it to be incorporated into early warning systems to safeguard the public against dangerous water contamination.

To control water quality, all point source and non-point source from vessels and facilities in the port must be controlled and monitored regularly to prevent pollution. Water needs to be treated quickly so that water contaminated because of oil spills for example, does not flow directly into the certain area. In addition, by involving stakeholders, especially those in technical support and geospatial data centers, in the planning process and data collection, their perspectives, knowledge, and interests can be considered, resulting in a more inclusive and informative approach to data coordination and management of water quality (Abdullah et al., 2016; Yatim et al., 2018).

Acknowledgements

This research was supported by Ministry of Higher Education (MOHE) through Fundamental Research Grant Scheme (FRGS/1/2021/STG08/UTHM/03/2) and Universiti Tun Hussein Onn through Research Enhancement Graduate Grant (RE-GG Q081).

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