ONLINE WATER MONITORING SYSTEM IN MALAYSIA: AN OVERALL ASSESSMENT

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FACULTY OF ENGINEERING
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DISSERTATION SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

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ONLINE WATER MONITORING SYSTEM IN MALAYSIA: AN OVERALL ASSESSMENT

ABSTRACT

Water monitoring is identifiable as a systematic analysis of water quality to identify and notify us of the current and ongoing status of the water bodies. It also highlighted emerging problems and the countermeasure that should contemplate in managing water quality. Water is not only crucial for industrial uses but also domestic usage. Untreated water can affect the ecosystem of living and non-living organisms. There are several methods of identifying the contaminants in the water bodies, such as the conventional approach and online water monitoring. The type of water monitoring implemented in Malaysia are manual water quality monitoring and continuous monitoring. There are only 15 stations for continuous monitoring, while there are almost 2000 stations for conventional monitoring. This research aims to propose the best online water monitoring model for Malaysia. Online water monitoring implements current technology such as sensors to identify contaminants that have disturbed the water elements' properties. This study aims to access the current online water monitoring practice in Malaysia and determine the best systems for online water monitoring based on the best practices. The data obtained in this research are from secondary data of the studies conducted in other countries. This particular data was chosen based on the technology and capabilities to be carried out in Malaysia. This work presents an analysis of recent works carried out in the system of online water monitoring. Also, best practices of online water quality monitoring based on the Internet of Things (IoT) method. The model developed is used in identifying the water sample, and data transmit in the cloud/internet/systems are analyzed. Water parameters such as color, odor, taste, and bacterial value are discussed as indicators to analyze water quality. In addition, federal and state government plays a significant role in managing water monitoring as they are the policymakers and the regulatory authorities.

Keywords: Water monitoring, quality, pollution, online monitoring, innovative solution

SISTEM PEMANTAUAN AIR DALAM TALIAN DI MALAYSIA: PENILAIAN KESELURUHAN

ABSTRAK

Pemantauan kualiti air adalah satu analisa sistematik bagi mengenalpasti tahap kualiti air yang dapat memberi amaran serta notifikasi/pemberitahuan kepada pengguna/pembekal terhadap status kualiti air secara semasa dan berterusan.Analisa ini juga memberi penekanan terhadap masalah yang bakal berlaku serta langkah pencegahan yang perlu dilakukan semasa menguruskan kualiti air.Air bukan sahaja penting untuk kegunaan industri tetapi juga untuk kegunaan domestik. Air tidak terawat yang dilepaskan melalui kumbahan boleh mempengaruhi ekosistem organisma hidup dan bukan hidup di sesuatu kawasan. Terdapat beberapa kaedah bagi mengenalpasti bahan cemar yang terkandung di dalam air seperti melalui pendekatan konvensional dan secara atas talian Kaedah mengenalpasti tahap kualiti air di Malaysia adalah menggunakan pendekatan konvensional dan secara berterusan. Terdapat hampir 2000 stesen pendekatan konvensional dan hanya 15 stesen secara berterusan yang terdapat di Malaysia. Oleh itu, kajian ini bertujuan untuk mencadangkan model pemantauan kualiti air secara atas talian yang terbaik Pemantauan kualiti air atas talian ini menerapkan teknologi terbaru seperti penggunaan sensors/pengesan bagi mengenalpasti bahan cemar yang terdapat di dalam sesuatu kandungan air yang boleh mengganggu gugat kualiti air tersebut. Objektif utama kajian ini adalah mengakses amalan semasa pemantauan air secara atas talian y'ang terdapat di Malaysia dan menentukan sistem terbaik berdasarkan perlaksanaan amalan terbaik. Dapatan data di dalam penyelidikan ini adalah data sekunder yang diperolehi dari kajian di beberapa negara. Data khusus ini dipilih berdasarkan penggunaan teknologi dan keupayaannya untuk diterapkan penggunaannya di Malaysia yang boleh digunakan untuk perbandingan. Pemantauan kualiti air secara atas talian ini menggunakan Internet of Things (IoT) melalui capaian Wi-Fi serta beberapa penerapan aplikasi yang lain. IoT merupakan salah satu daripada amalan terbaik di dalam pemantauan secara atas talian. Parameter air seperti warna, bau, rasa dan nilai bakteria (bacterial value) boleh menjadi indikator awal bagi mementukan kualiti air. Tambahan pula, pihak berkuasa

negeri bersama kerajaan pusat, yang bertindak sebagai pembuat polisi dan penguatkuasaan undang-undang, memainkan peranan penting di dalam pemantauan pengurusan kualiti air.

Kata kunci: **Pemantauan air, kualiti, pencemaran.pemantauan dalam talian, penyelesaian pintar**

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LIST OF SYMBOLS AND ABBREVIATIONS

DOE	Department of Environment
MESTECC	Ministry of Energy, Science, Technology, Environment and Climate change
UNDP	United Nations Development Program
UNICEF	United Nations International Children's Emergency Fund
IoT	Internet Of Things
WQI	Water Quality Index
IR4.0	Industrial Revolution 4.0
BOD	Biochemical Oxygen Demand (mg/L)
DO	Dissolved Oxygen (ppm/mgL)
WTP	Water Treatment Plant
WHO	World Helath Organization
RTC	Real Time Control
TOC	Total Organic Carbon (mg/L C)
SS	Suspended Solids (mg/L)
OWQM	Online Water Quality Monitoring

CHAPTER 1: INTRODUCTION

1.1 Introduction

Water is significant for humans, animals, and plants to survive. The reflection of the water gives off blue light and creates a blue marble glance to the earth as half of the planet is covered with water. The characteristics of water, such as tasteless, odorless, and transparent, add value to the quality of the water. According to Gleick (1993), the percentage of earth surface sheath by waters comprised almost 71 percent, while the oceans occupied 96.5 percent of the earth water. It also can exist in the form of air, lakes, glaciers, ice caps, and groundwater as aquifers. Although the planet is sheath in water, only 0.3 percent is usable by human beings. Even though it is useable but it is still unattainable.

Then, most organisms and human body weight consist of 60-90 % percent of water, the brain and heart comprise 73% water, and the lungs are about 83% water. The skin contains 64% water, muscles and kidneys are 79%, and even the bones are watery by 31% (H.H. Mitchell, 2017). It shows vital signs that humans need to drink and consume water according to their gender, age, and the surrounding temperature that can affect an individual. Our water intake is not on the water we drink, but the food we consume daily plays a role in contributing to our body's percentage of water.

Therefore, clean water is necessary for good health, and if the water is contaminated, it can jeopardize our health. At the same time, it can cause numerous concerns on health such as viruses and bacteria, which might give a long-term exposure that can lead to severe illnesses such as heart disease. Monitoring water quality is the best way to provide clean water to the community as it can change almost everything. It reminds us why clean water has become an essential agenda in Sustainable Development Goals (SDG 6). Clean water is not necessarily about contamination but improving the water quality by reducing the pollution or any activities to eliminate dumping and minimize the hazardous chemical release in water bodies. According to the statistics data from UNDP, there are only 71 percent of the global population has access to safe drinking water, while there are 844 million people are still unable to have safe access to drinking water. These statistics highlight concerns as it is an alarming situation faced by the nations. Last year, around 1 in 4 people lacked safely managed drinking water in their home, and half of the world population lacked safely managed sanitation (UNICEF,2021)

Furthermore, there are a few water monitoring methods, such as the conventional and online monitoring approaches. Traditional water monitoring uses bottle sampling (Spot sampling), extraction, and instrumental analysis (Yusef et al.,2019). Online water monitoring represents more details and information on water quality in water bodies. It can provide information to protect the public water supply for all intended uses. It allows us to observe long-term trends to prepare for the future and implement regulations immediately. Online water monitoring uses online instruments to capture real-time water quality measurements, whether in source water or distribution systems. The parameter readings are part of monitoring as each parameter has its value that indicates the condition of the water.

On the contrary, water resources in Malaysia are mainly from rivers, lakes, and groundwater. There are no actual dry seasons in Malaysia. It has indirectly impacted almost 200 rivers system in Malaysia. The main contributors to Malaysia's water pollution are urbanization, population growth, land clearing, increasing commercial areas, industrial effluent discharge, domestic effluents, and agricultural activities. Regulatory agencies identify two main categories of pollution, point sources and non-point sources (WEPA, 2020). Point sources can be identify as they come from a single place, such as smokestacks, discharge pipes, and drainage ditches in factories and power plants that can affect air and water. The discharged effluent usually contains harmful chemical pollutants released without treatment in the water bodies.

In comparison, non-point sources are harder to identify as it comes from many places, all at once. The thunderstorm can bring the runoff into the storm sewer and end on nearby rivers. It washes away almost all elements such as trash, waste, and others that will end up together in one place.

Further, the legislative framework for water environmental governance in Malaysia follows on Environmental Quality Act 1974 (Act 27). Water governance in Malaysia involves the federal government, state government and the several agencies in monitoring the water quality. The federals government includes several departments that work together such as Department of Environment (DOE), Ministry of Energy, Science, Technology, Environment and Climate change (MESTECC), and Water Service Industry Act (WSIA) 2006 (ACT 655). The main objective of these department mainly as policy makers, responsible in regulatory frameworks and establish licensing. This act did not affect existing laws on environmental quality, land matters, or state powers regarding water sources (WEPA,2020). Plus, for water quality-related standards and indexes, we can refer to or based on National Water Quality Standards for Malaysia, Water Quality Index for rivers, Malaysia Marine Water Quality Standard and Index, and National Standard for Drinking Water Quality (2000).

1.2 **Problem Statement**

Preventing and conserving water from contamination is vital in assuring the continuing abundance of safe water. Keeping water from being contaminated is essential as it can affect our health. The primary source of water contamination is usually industrial effluents (EPA,1997). Last year, Malaysia faced dry taps for four days, impacting more than 1 million shareholders in Klang Valley. These sudden water cuts cause chaos, anger, and frustration in the community due to the illegal dumping of industrial effluent that impacts the water quality in the water bodies (Wong,2020). According to Air Selangor, the contaminants in Sungai Selangor have been eliminated by flushing water from Sungai Selangor and Sungai Linggi dam. Approximately 300 million liters are needed to dilute that solvent to restore water quality to the safe consumption standard by affected account holders. It is time critical when dealing with contamination, as immediate approaches need to be taken into account to avoid the incidents worsening.

Next, tremendous research has been developed to find an efficient method of determining the contaminants in the water that require accurate and fast response detection. An advanced water monitoring system must be implemented with the latest technology to reduce wastewater's impurities and detect them immediately. According to Alam Sekitar Malaysia (ASMA), they have started the works by implement online water monitoring is several areas in Putrajaya in order to monitor the water distribution network. Online water monitoring can be proposed; this method uses online instruments and captures actual time measurement of water quality, whether at the point of source water or in the distribution system. This is the modern and most innovative way of analyzing data continually and the capability to instantly notify users of any changes that happen in the water bodies (S.Geetha & S.Gouthami, 2016).

1.3 Research Questions

1. What are the systems used in online water monitoring currently?
2. What is the best practice for online water monitoring?
3. What are the parameters that are necessary for online water monitoring?
4. Who are the responsible bodies involved in online water monitoring?

1.4 Research Aim

This research aims to propose the best online water monitoring model for Malaysia.

1.5 Research Objectives

The objectives of this research are as follows

1. To assists current online water monitoring practices in Malaysia.
2. To propose the best system for online water monitoring in Malaysia based on the best practices.

1.6 Scope of Research

This research is conducted to propose Malaysia's best online water monitoring model. The data obtained in this research is based on articles, journals, and research conduct over the past few years. This scope of the study is only for treated water. In addition, treated water is the treatment of raw water in a crucial stage in production for the water to be used by industries and for consumption.

1.7 Significant of Research

Water scarcity or water crisis can be defined as a health crisis that been affected millions of people. People are dying due to water-borne diseases such as cholera and typhoid fevers due to a lack of accessibility to water and inadequate sanitation provided by the government. Then, water systems such as rivers, lakes, and aquifers are drying or polluted due to globalization. This will affect the water quality. We need to maintain the water quality system in our countries to protect our water supplies or water disruption that can affect the community or the residential area in the nearby locations.

Water pollution has become a significant concern in most countries; technology such as the implementation of IoT (Internet of things) has been reviewed and even adopted in several countries to help them monitor the water quality in real-time. This has become one of the methods used other than probes and laboratory analysis. The main parameter will be analyzed to determine water quality, such as temperature, PH, turbidity, Chemical Oxygen Demand, Dissolve Oxygen, Biochemical Oxygen Demand, Ammonia Nitrate, and Suspended solid. Hence, we need to develop a better monitoring method such as a real-time water monitoring system to detect the contamination earlier before it disrupts or damages the water bodies. Prevention is better than cure as it incurs the most and is usually costly.

1.8 **Report outline**

This research consists of five chapters as follows:

1. Chapter 1- Introduction

   This chapter covers the background of the research and brief information on the importance of water to the populations, accessibility of clean water, its effect on health, and types of water monitoring. Besides, this chapter discusses the study's problem statement, aim, objective, scope, and significance.

2. Chapter 2- Literature Review

   This chapter discusses previous and current findings on water footprint, water quality index, and types of monitoring. It also reviews the latest trend of water quality status in Malaysia, including rives classification. Discussion on pollution and the monitoring framework has also been highlighted here.

3. Chapter 3- Methodology

   This chapter explains the method used to gather the information and data relevant to this study. The technique used in this is through the previous research paper and current studies.

4. Chapter 4- Results and Discussions

This chapter involves results obtained in proposing the best online water monitoring model. This chapter will further analyze, discuss, and review the proposed model.

5. Chapter 5 – Conclusion and Recommendations.

This chapter summarizes the overall findings of online water monitoring while accessing if the study's objective was met—all the recommendations and suggestions for future studies being highlighted.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter begins with the literature review of the definition or meaning of water monitoring. Then, the significance of water monitoring for water quality and the types of water monitoring available in Malaysia are discussed. Most contaminants that affect water quality are due to water pollution, and the causes are also discussed in this chapter. The water quality index (WQI) has been an important indicator to determine the level of water quality, and it has also highlighted the importance of each parameter. On the other hand, the water quality monitoring framework has been highlighted.

2.2 Water footprint

Water footprint (WF) can act as indicator in tracking the human pressure on the water supply. This is one of the footprints in the footprint family that integrate ecological and carbon footprints (Galli et al., 2012; Ewing et al., 2012). The introduction of WF was developed in the year of 2002 (Hoekstra et al., 2009). This concept has been highlighted to shows the relationship between the needs of human consumption and the global dimensions of water governance (Hoekstra et al., 2009). The evaluation of WF contemplates water used by several parties, such as the individuals, the area, and others. The main idea is to promote efficient water management to be able to compare the water supply and demand in the chain areas. The WF views the life cycle of water usage as direct and indirect. Indirect use can be refers as embodied water, which refers to the total amount of water embedded in the supply chain for the production of goods or services. (Hoekstra et al., 2009). While direct use is direct water consumption by consumers or producers. WF represents the spatial distribution of a country's water demand based on consumption and industry needs.

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2.3 Water usage by different industries

In 2025, it is expected that half of the population will be affected by water scarcity, as in every continent. Water is mainly used in domestic and industrial usage. Industries consume high water consumption than domestic use. According to the United States Geological Survey (USGS), they use water in production, washing, smelting, etc. A large amount of water is used mainly to produce food, paper, and chemicals. All industries have their water footprint. The volume of water intake through the whole supply chain to produce the product in industrial and domestic water usage is different for both parties as industrial use more water. It creates contamination in industrial wastewater that requires more water to dilute the contaminants solvents to meet the standard requirements to be released in the water bodies (B.M.Fekete, 2013). The industries that consume the highest volumes of water are agriculture, fashion, energy, meat, beverages, construction, mining, and car (Iulia Georgiana, 2021). The annual water use globally is estimated at around 4600 billion cubic meters, with approximately a one percent growth rate yearly (Kurniawan et al.,2021). Most water consumption is used in energy production, agriculture, human consumption and industrial use. The water consumption in Malaysia can be summarized in Figure 2.1, data accumulation is the estimation from 2010 until 2018 (Kurniawan et al.,2021).

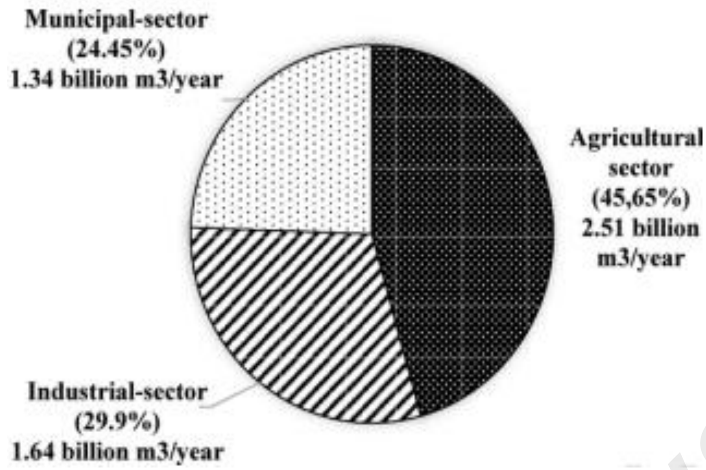

Figure 2.1: Water consumption in Malaysia

2.4 **Environmental water monitoring**

Environmental water quality monitoring provides data to safeguard the environment against adverse biological effects from contamination from anthropogenic diffuse emission and point sources (Altenburger R. et al., 2019).

Monitoring contemplates various purposes, from chemical and ecological compliance to safeguarding water use. Several water sampling techniques, chemical target analysis, and methods were introduced to improve water contamination monitoring. Significant advancement for broader applicability includes sampling technique, screening, diverse set of chemical, detention sensitivity, protocols for chemical and toxicology, and others. A single method and combination method can't meet all monitoring purposes. For instance, SOLUTIONS, the international EU- the funded project, has implemented environmental monitoring to shift water monitoring from a few legacies of chemicals to a complex chemical mixture.

2.5 Importance of water monitoring

Water monitoring is vital so that people have access to safe water. The water quality and its source need to be safe enough to be used, consumed, and for irrigation purposes. Next, it helps the researcher to forecast and understand the natural water cycle in the environment and as well as to analyze human impacts on the system. The ultimate aim is to ensure environmental standards are abiding. Human activities treat and pollute most of the freshwater (Romshoo & Rashid, 2012; Torbick et al., 2013). They maintain the ecosystems' good health and can reflect the condition of the surface water bodies in the set duration and time (Prashant K et al., 2020). Water monitoring identifies the situation and condition of the aquatic living organism and how that could have affected human activities by introducing contaminated and untreated wastewater into water bodies (J. Bartram & R. Balance, 2020). It also can be defined as a set of data required in order for the purpose to protect the environment against any issues in regards to chemical contamination that can cause by point sources and others.

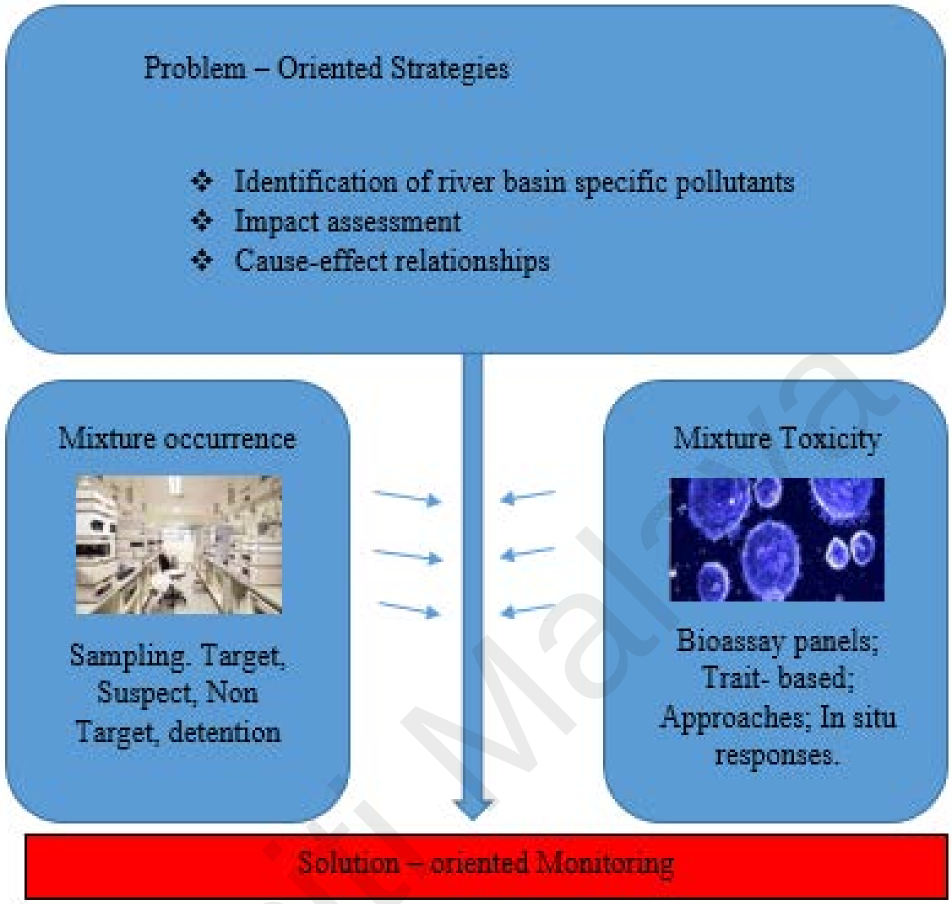

Figure 2.2 : The solution oriented monitoring

2.6 Type of water monitoring

Contamination of water bodies can negatively impact human health. It is crucial to ensure the water quality standards are according to the minimum standards that regulations have set. Identifying the type of contaminants and understanding the readings of each parameter gives an idea of the quality of the water body. Contamination can be caused by anthropogenic and natural genic conditions worldwide. The critical step in implementing water quality management strategies is monitoring and sensing the level of contaminants correctly. Doing it can reverse the problem and, at the same time, improve the water status. Despite this, stricter regulatory frameworks and public concerns can demand more effective ways to monitor water quality by detecting pollutants and contaminants within the water bodies (A.D.D.Diamond et al., 2021). In turn, this has driven the researcher to develop a more online water monitoring approach than the traditional method of water monitoring. The details of each water monitoring approach will be discussed as follow:

2.6.1 Conventional monitoring approach

The conventional water monitoring approach is by using in situ and laboratory analysis. The researcher has used this method to inspect the consistency of water quality, usually in the water bodies that become a source of our consumption. The researcher needs to collect the water sample manually and ship the sample to the laboratory for analysis. They will run a few tests on the sample to identify the primary contaminants so that accurate prevention or countermeasure can be taken into action immediately. This technique requires more time, wastes energy, and is no longer profitable (SV Aswin Kumer et al.,2020). In addition, if water pollution can be detected early, suitable countermeasures can be taken into action, and critical situations can be avoided (V. Lakshmikantha et al., 2021).

This conventional approach is labor-intensive as it requires more people to collect the sample (Xiao Sun et al., 2021). Traditional water quality monitoring requires manual collection of water samples at periodic locations on the stated time intervals, a centralized storing site, and the need for laboratory testing on the sample. (Thinagaran et al., 2015). This water monitoring approach is not considered efficient due to the unavailability of real-time water quality information, delayed detection of contaminants, and not a cost-effective solution. Conventional sampling approaches suffer from several limitations; such are:

1. The spot water can only reflect residue composition during the sampling moment and fails to detect continuous contamination.
2. Physical difficulties in handling a large volume of water or samples during extraction, collection, and tracing it can affect the quality.
3. The conventional methods are labor-intensive and expensive to be implemented in the system.
4. The concentration of dissolved contaminants is not accurate by most conventional methods.

2.6.2 Online monitoring approach

Water quality monitoring is the primary step in water resources management; if the monitory process is more accurate and cost-effective, it can test more water and protect the water bodies from such casualties (Chowdury et al.,2019). The conventional ways of the monitory approach are more expensive and labor-intensive. For the past few years, this approach has been undergoing a drastic change and the implementation of technologies with more effective ways to collect and monitor water quality.

Online monitoring developed with the implementation of technology. It has become mandatory to gather information to the maximum extent (Wijeyaratne & Nanayakkara, 2020). The fourth revolution (IR 4.0) has changed water quality monitoring entirely. The paradigm shift has initiated technological innovation, and also there has been a massive sustainable transformation in various industries and sectors (Kumar et al.,2020). It is also including water quality monitoring. The IR 4.0 can connect not only people but process and data in network connection to fully utilize (Awan et al., 2021). In addition, the Fourth Industrial Revolution was fueled by digital transformation. There are nine pillars of Industry Revolutions 4.0: augmented reality (AR), System Integration, and cloud computing. Big Data, IoT, 3D Printing, Cybersecurity, Autonomous robots, and simulation. Among the main pillars, 3D, IoT, and cloud computing have been implemented for online water monitoring. This is hope to be able to address present challenges with inadequate monitoring. Therefore, the potential damage due to contamination can be reduced significantly and rapidly due to the effective response. Online water monitoring has become a vital approach that has been implemented. (Vijayakumar & Ramya, 2015)

The significance of online water monitoring such are:

1. Ability to detect and respond to contamination
2. Optimize the treatment process to improve the finished water quality and able to reduce cost
3. Develop information that supports regulatory compliance
4. Provide real-time analysis of the water quality, and immediate action can be taken to identify the changes in parameters.
5. Identify measurement of critical water quality parameters such as microbial, physical, and chemical properties.

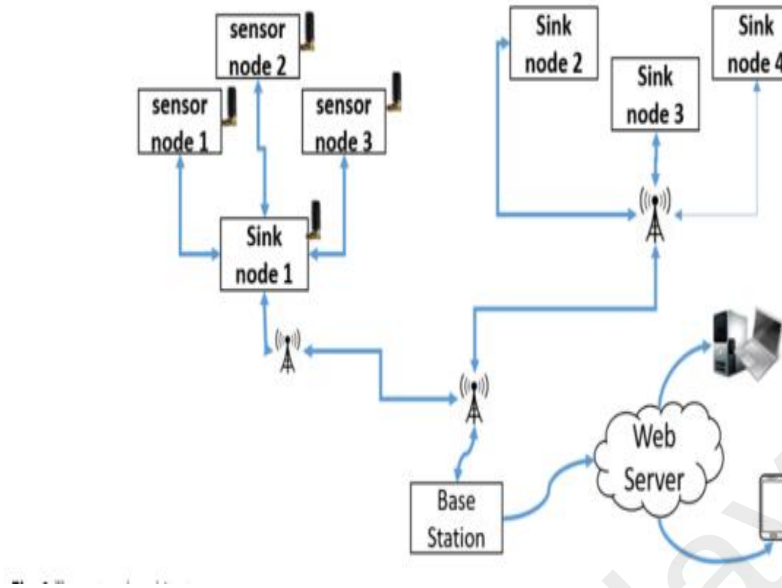

Figure 2.3: Overview of online water monitoring systems

Figure 2.3 shows the systems designed and implemented with the main idea of monitoring the water quality based on several parameters considering the systems. This system can be implemented in broad areas, storing information in the cloud and delivering real-time scenarios and notifications to the authorities and end-users. This system can provide several applications such as data storage, data dissemination, power management, and maintenance of the administrators (Demetillo et al., 2019).

2.7 Trend of the river water quality status in Malaysia (2017 - 2018)

The total number of rivers in Malaysia has fluctuated for the past ten years. But, is an increase from 477 rivers in 2017 to 638 rivers in 2018. The total number of samples is 8118, with 1353 monitoring stations. This monitoring station can be divided into a few stations as such:

- 1263 monitoring stations for ambient and baseline
- 55 monitoring stations for upstream water intakes

- 35 monitoring stations for the river of life (RoL) project

Based on the finding, the total numbers of clean rivers are 357 rivers which represent 56% percent of the total rivers, slightly polluted rivers with the numbers of 231 rivers, represent 36% percent and polluted rivers are 50 rivers with 8% of the total number of rivers (WEPA, 2020). Data is represented as follows:

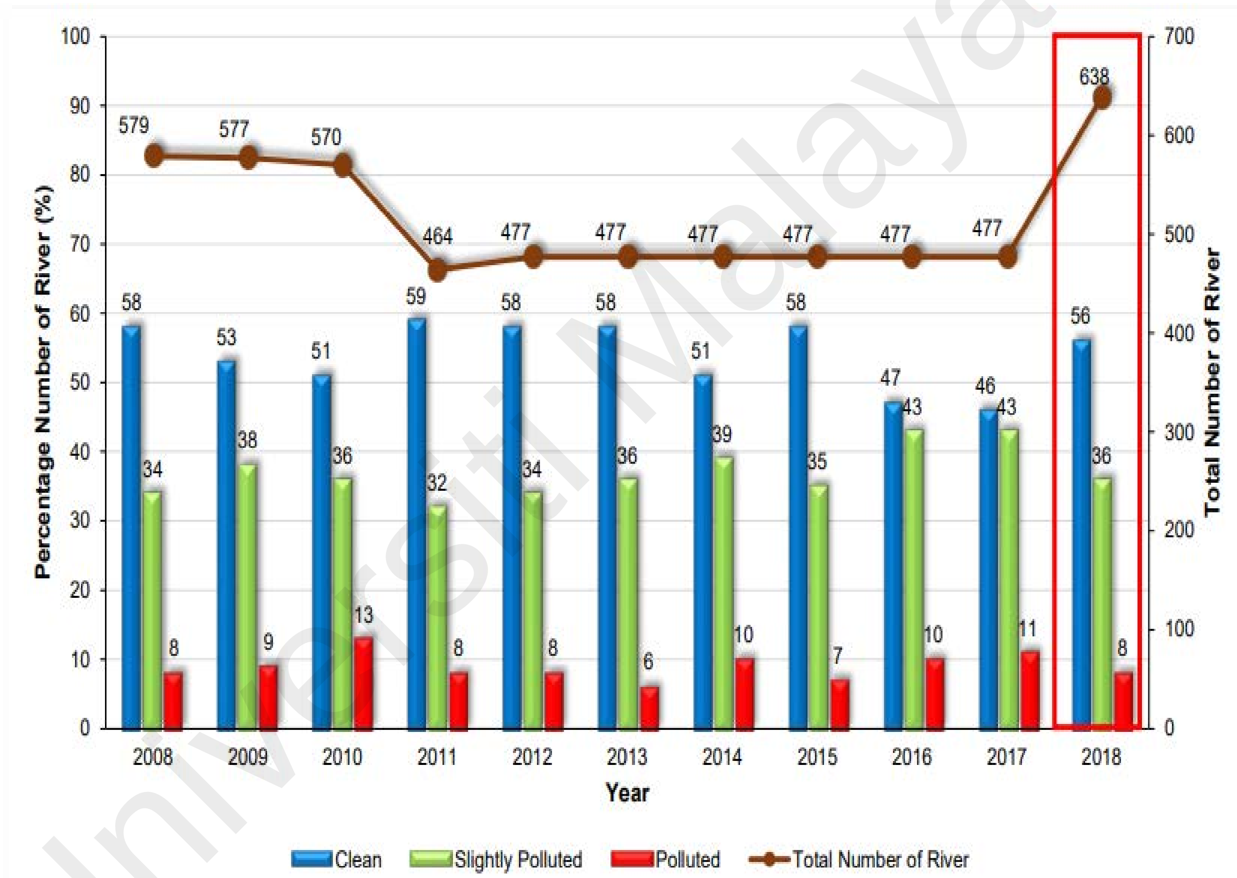

Figure 2.4: River water quality status in Malaysia from 2008 until 2018.

2.8 Classification of river water quality in Malaysia (2017 - 2018)

The water quality index has been used to describe the condition of water bodies. This is one of the quick and most straightforward methods to be used by looking at the single aggregate value and the corresponding scale. Several important parameters in WQI calculation are the value of Ammonia Nitrogen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, pH, and Total Suspended Solids. The overall reading of each parameter can identify the classification of water quality and the required type of treatment.

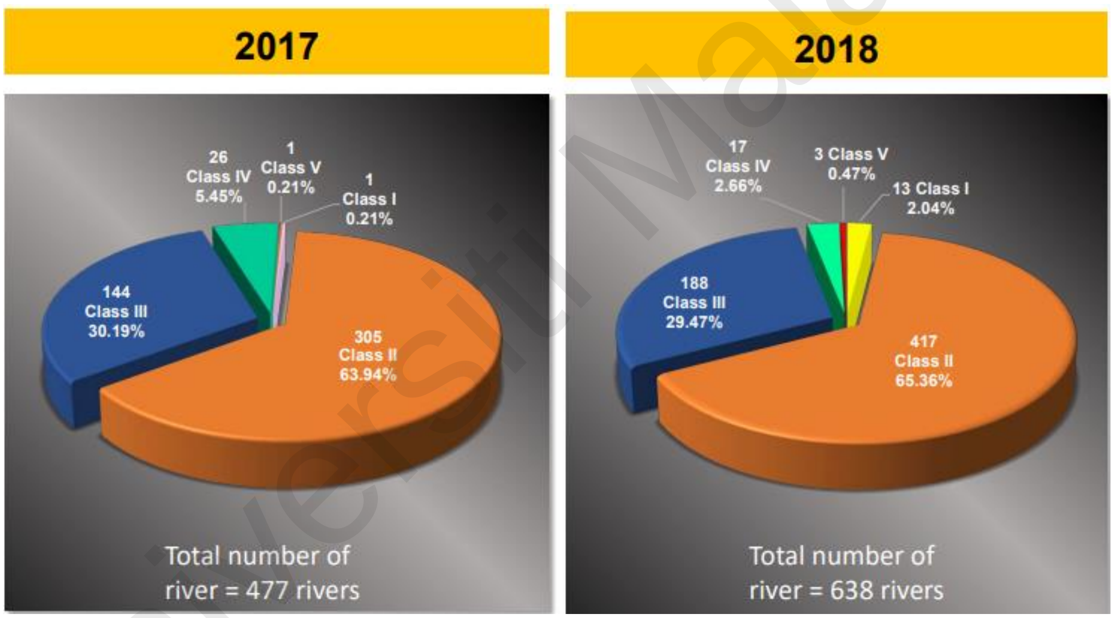

Figure 2.5: Condition of rivers quality from year 2017 to 2018

Figure 2.5 shows the condition of rivers in Malaysia from year 2017 to 2018, from the percentage we can see that the total numbers of rivers increase in the year of 2018 and also it effect the percentage of each classification of rivers. According to the Department of

Environment (DOE), there are five classifications that the public can be used to refer to as a standard guideline:

- Class I: WQI < 92.7%, At this stage, the water bodies required no treatment.
- Class II: WQI between 76.5-92.7%, Conventional treatment is needed to recover the water bodies
- Class III: WQI between 51.9-76.5 %, Extensive treatment required in the treatment of the water bodies
- Class IV: WQI between 30.0-51.9%. Irrigation
- Class V: WQI > 31.0, None of the above matters

The index range from WQI: Clean (81-100), Slightly Polluted (60-100), Very polluted (<59)

2.9 Water pollution

Water pollution can be defined as contamination of water sources by any substance that makes the water unusable for consumption, daily use, drinking, and others. Pollutants can exist as parasites, bacteria, trash, and chemicals. Any form of pollution will end in water bodies. The pollution chain can start on land and end up in the ocean. The introduction of harmful substances can contaminate water bodies, affect water quality, and be toxic to humans and the environment (Melissa Denchak,2018). Water pollution is not a phenomenon that is happening in Malaysia, but it has become an international issue for many developing countries (Mridul Dharwal., 2020)

2.9.1 Causes of water pollution

Water is universal solvent as it can dissolve more substances than any other liquid. Plus, this is why the water is so easily contaminated. This toxic substance usually comes from factories and industrial effluent discharged without treatment and can cause water pollution. Several activities and industry can causes the water pollution such as from industrial waste, sewage and wastewater, marine dumping, oil leakage accidents and others.

2.9.2 Sources of water pollution

The sources of water pollution can come from groundwater, surface water, ocean, point sources, non–point sources, and transboundary. Each of the categories impacts the water properties in the water bodies.

2.9.2.1 Groundwater

The groundwater source is from the rain that falls into the earth and becomes groundwater. This is one of the most critical natural resources and is mainly used for drinking water. The pollutants come from vary activities but the use of pesticides and fertilizers waste leaching from landfills and other systems that make their way into the aquifer and are unsafe for human use. Groundwater can spread contaminants far from the original location of the polluting source. If groundwater gets contaminated, it will be unusable for decades, and treating the groundwater is more expensive and takes years to recover (EPA,1988)

2.9.2.2 Surface water

Surface water consists of 70% percent of the earth, and it fills our oceans, lakes, and rivers. Originally from freshwater sources that have been used by more than half of the population in America. Nevertheless, half of the rivers are polluted and unable to be used for any activities. The type of contaminants that are mostly found in freshwater sources is nitrates and phosphates. Excess nutrients can harm the algal blooms in the area, and pathogens in water bodies can harm human health (Borthakur, A., & Singh, Pardeep.,2020))

2.9.2.3 Ocean Water

Ocean pollution is also known as marine pollution happens when contaminants from land, inland, coast areas, the industry or cities by the streams and rivers into bays and estuaries debris travel out to the sea. Marine debris such as plastic is usually blown by the wind or washed in storm drains and sewers (Jenny, 2019). Oil spills can also cause ocean pollution.

2.9.2.4 Point Source

Any contamination that is originally from a single source is called a point source of pollution (EPA, 2018); for example, wastewater treatment plants discharge legal or illegal effluent into water bodies. It can originate from one specific place that can affect miles of waterways and the ocean.

2.9.2.5 Non-Point Source

It is ha rd to identify a non-point source of water pollution since there is no single identifiable culprit—one of the significant issues most countries face. Contamination from diffuse sources (EPA, 2018).

2.9.2.6 Transboundary Sources

Transboundary water pollution involves more than one country being affected. For example, contamination from disaster events such as oil spills in our territory can contaminate water from other countries (Helena, 2019).

2.10 Water Quality Index (WQI)

The water quality index has become the indicator to measure the water quality of the water bodies. It will express comprehensive information on the current conditions of the water quality by providing single numbers. The objective of WQI is to express data information in an understandable and useable form to the public. There will be a few parameters needed in the WQI calculation. WQI summarizes the condition of the water quality into a single meaningful values. The single value can be used to compare data from several sites. WQI encompasses the impact of physical and chemical parameters on water quality and is an effective tool for converting convoluted parameters into more comprehensible forms (Jyothi SN et al., 2020).

Water quality monitoring is vital to achieve the objective rehabilitation of waterbody or waterways. The output from WQI readings determine the water quality status, and the categories based on the index value. There are six main parameters which are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia Nitrogen (AN), Acidic and Alkaline (pH), Dissolved Oxygen (DO) and Total Suspended Solids (TSS) (Nor Zaiha et al, 2013).

The formula for Water Quality Index (WQI)

WQI = 0.22(SIDO) + 0.19(SIBOD) + 0.16(SICOD) + 0.15 (SIAN) + 0.16(SISS) + 0.12(SIpH)

WQI: Water Quality Index

SIDO: Sub Index Dissolved Oxygen

SIBOD: Sub Index Biochemical Oxygen Demand

SICOD: Sub Index Chemical Oxygen Demand

SIAN: Sub Index Ammonia Nitrates

SISS: Sub Index Suspended Solids

SIPH:Sub Index pH

2.11 Parameters for Water Quality Index (WQI)

2.11.1 pH

It is essential to identify the PH of the waterways, either acid, alkaline or neutral. The water ph needs to be in a regular reading as it can affect the ecosystem of the living organism in the area. The ph value can be divided into three classifications that are alkaline, acidic, and neutral. High organic pollution will turn acidic. If PH's value is seven, it is indicated as neutral, and less than seven it can be grouped as acidic, and more than seven know to be alkaline.

2.11.2 Dissolved Oxygen (DO)

DO is one of the most essential parameters in classifying the waterways in the WQI. DO values, and WQI are related; if DO readings are lower, the WQI value will also show the same pattern. This value is based on the surrounding activities that can cause the depletion or increase the DO readings based on the organic pollutants released. Detergent, rubbish, and grease tend to block the oxygen from dissolving into the water bodies (Nor Zaiha et al., 2013).

2.11.3 Chemical Oxygen Demand (COD)

The third most important parameter in WQI is COD, and the average value in waterways are usually between 0 to 150mg/L. The factors that effects the COD value are based on the content of organic substances non-biodegradable and reactive. Domestic waste also contributed to the high content of COD values. These effluent are toxic and dangerous to the ecosystem and can affect the sustainability (Nor Zaiha et al, 2013).

2.11.4 Total Suspended Solids (TSS)

Suspended solids that did not pass through the filter paper during laboratory experiments are called suspended solids. Any particle that ends in the land of the rivers contributing the increasing of suspended solids in the waterways (Nor Zaiha et al, 2013).

2.11.5 Biochemical Oxygen Demand (BOD)

BOD and DO are related as the leading indicators of organic pollution in rivers. If DO value is decreased, the BOD readings denote an increase. The second important parameter is identifying the WQI classifications. BOD concentration can be high due to commercial activities and residential areas along the waterways. Untreated sewage and food waste are the contributors that can increase the BOD content in the rivers. (Nor Zaiha et al., 2013).

2.11.6 Ammonia Nitrogen

The main source of ammonia nitrogen is from microbial degradation of nitrogenous organic matters. It can also come from the sewage treatment plant, fertilizers for agriculture, and other by-products that flow into the waterways (Nor Zaiha et al, 2013).

2.12 Water Quality Monitoring Framework

2.12.1 Marine Water Quality Monitoring

The Department of Environment, Malaysia, will execute this monitoring under Environmental Quality Monitoring Programed (EQMP). This monitoring aims to establish marine WQ status and the pollution level from land-based and sea-based sources. In 2018, the total number of monitoring stations was 368, which 188 stations in the coastal area, 85 stations in the estuary, and 95 stations on the selected island. The frequency of sampling is 6 times/year. The parameter that has been monitored are in situ with six parameters and laboratory with 23 parameters involved. Plus, Marine Water Quality Index (MWQI) reflect the water quality status as either excellent to poor, and the parameter involved are DO, NO3, PO4, NH3, fecal coliform, O&G, and TSS. It is based on Marine Water Quality Criteria and Standards. (DOE EQR 2018).

Table 2.1: In- Situ & Laboratory Measurement

No	PARAMETER	CODE	UNIT
	In- situ measurement		
1	Dissolved oxygen	DO	Mg/I
2	Ph	pH	-
3	Salinity	Sal	Ppt
4	Temperature	Temp	C

Table 2.1 Continued

No	PARAMETER	CODE	UNIT
	In- situ measurement		
5	Turbidity	Turb	NTU
6	Conductivity	Cond	Ms/cm
	Laboratory Measurement		
1	Total suspended solid	TSS	Mg/I
2	Oil and grease	O&G	Mg/I
3	Tarball	Tar	g/100m
4	Mercury	Hg	µg/I
5	Cadmium	Cd	µg/I
6	Chromium	Cr	µg/I
7	Copper	Cu	µg/I
8	Arsenic	As	µg/I
9	Lead	Pb	µg/I
10	Zinc	Zn	µg/I
11	Cyanide	CN	µg/I
12	Unionized Ammonia	NH3	µg/I
13	Ammonia Cal Nitrogen	NH3N	µg/I

Table 2.1 continued

	Laboratory Measurement		
14	Nitrite	NO2	µg/I
15	Nitrate	NO3	µg/I
16	Phosphorus	PO4	µg/I
17	Phenol	Phenol	µg/I
18	Tributyltin	TBT	µg/I
19	Total coliform	TC	MPN/100
20	Faecal coliform	FC	MPN/100
21	Escherichia coli	E-Coli	MPN/100
22	Enterococci	-	MPN/100
23	Polycyclic aromatic hydrocarbons	PAHS	µg/I

2.12.2 Groundwater Quality Monitoring

DOE has implemented groundwater monitoring since 1997 for Peninsular Malaysia and in 2003 for Sabah and Sarawak under National Groundwater Quality Monitoring programed. The total stations are 119 stations, 93 stations in peninsular Malaysia, 14 stations in Sabah, and 12 stations in Sarawak. An additional ten monitoring station has been developed under the 11th Malaysia Plan Project (2017-2018). In 2018, it is stated that there are 109 tubes of wells and this monitoring base has specific land usage such as:

- 13 tubes for agriculture
- 12 tubes for Urban and Suburban
- 19 tubes for Industrial sites
- 23 tubes for solid waste
- Seven tubes for the Golf course
- Four tubes for Rural areas
- Three tubes for Ex Mining
- Five tubes for municipal water supply
- 14 tubes for the Animal Burial area
- Seven tubes for Aquaculture Farms
- 1 tube for Radioactive Landfills
- 1 tube for resort

The measurement method that has been used for groundwater monitoring is in situ with six parameters and laboratory analysis with 11 parameters. The sampling equipment that has been used is a hydro lift pump, HDPE Tubing, Water depth sensors, generator, cool box, and others. Malaysia Groundwater Quality Monitoring represents the groundwater quality status and category based on a scale of 1-100, which indicates very poor to excellent. An example of a parameter that has been analyzed in this monitoring is pH, iron, TSS, nitrates, e-coli, phenol, and sulfate. (DOE EQR, 2018)

Table 2.2: Groundwater Monitoring analysis

Analysis method	Parameter	Picture
In situ	Temperature,PH, Conductivity, Turbidity, salinity, Dissolved oxygen	
Lab	VOC, Hydrocarbons, total coliform, Phenolic compound, Radioactivity, Total hardness, Total Dissolved Oxygen.	

2.12.3 Surface Water Quality Monitoring (SWQM)

DOE has implemented surface (River) Quality Monitoring since 1978, and comprehensive since 1995 under EQMP since 2017. In 2018, The total rives of 638 with total stations of 1353 with manual monitoring and 30 automatic monitoring stations that handle 8118 samples. The total frequency of sampling is 4-12 times/year and monitoring 30 parameters. WQI has been implemented to indicate the pollution level and suitability in terms of water usage according to the National Water Quality Standards for Malaysia (NWQS). There are six parameters involves (DOE EQR 2018).

2.13 The Current Practices for River Water Monitoring in Malaysia

The main ideas of monitoring are to fulfill the requirement to publish the annual report on environmental quality by Department of Environment. There are several objectives that need to be achieve such as to classify the environmental resources by planning the development and utilization of water resources, collection of baseline data, environmental surveillance and investigate any incidents due to pollution event and provide corrective measures. Water quality monitoring activities were privatized to ASMA (Alam Sekitar Malaysia Sdn Bhd) on 1st January 1995. This involves manual and automatic/continuous monitoring. There are almost 2000 manual monitoring stations and there are only 15 automatic water quality monitoring stations installed in sensitive locations in Malaysia (DOE). There are several parameters involves in manual water quality monitoring such as Dissolved Oxygen, Turbidity, Conductivity, and salinity for in- situ measurement and there are 24 chemical and biological parameters involve for lab analysis. Further, for continuous water quality monitoring there are only 15 stations and its located in sensitive areas. The idea of this implementation is to detect the changes in river water quality in continuous basis and to urge immediate inspection will be conducted at suspected site.

2.14 Summary of Literature Review.

Overall, this literature review provides a brief overview of the importance of water to people, the environment, and industries. It is not only vital but it is needed for everyone to monitor the water quality accordingly. The water footprint calculation has become the solution for most industries player to calculate and identify the total volume of freshwater used to produce goods and their services as industries consume a large amount of water. The significant water values give an add-on value in monitoring the water quality. Water conservation is necessary as we know it will demise sooner, and it is a non-renewable natural resource.

Several types of water monitoring, such as conventional and online water monitoring. Both the monitoring help prevent contaminants from jeopardizing the water quality in water bodies. Both have their accuracy, capacity, capabilities, and time constrain. We have used the conventional method, and most researchers find it costly and time-consuming. Implementing the online monitoring approach can provide real-time analysis that authorities can monitor through the IoT system. This system is the best practice in water monitoring and can notify the end-user of the current water quality status. Parameters are important in identifying the level of water quality, and necessary parameters must be used based on the study's aim.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter summarizes the specific procedure and method used to conduct the research. Further explanation of how the necessary data was retrieved, processed, and analyzed to achieve the stated objective will be discussed here. All the data are interpreted and discussed in Chapter 4 (Results and Discussion). The data obtained in this research are from secondary data of the studies in another country. This particular data was chosen based on the technology and details it provides and the capabilities to be implemented in Malaysia. The other factors considered in choosing this set of data are based on the followings:

I. The implementation and approach that exist in online water quality monitoring.

II. Abilities to implement the systems as it less complex and low cost to maintain.

III. Implementation of sensors in providing online data to consumers.

This data includes the application implemented in the water monitoring system, types of sensors used, communication technology, and others. It will highlight a less complex water monitoring system inbuilt with Wi-Fi to monitor the parameters readings. Any changes in the readings, the system will notify the user of the deviation in water quality.

3.2 Research Method

The research method helps in organized, determining, and accumulating data not only for the purpose of analyzing but also to attend to the research question. This methodology usually based on the research aim and research problem. Sometimes, words hardly to express the appropriate definition of the findings. There are two methods in research methodology: Qualitative and quantitative research. For this research, we are using a qualitative method interpreting the data as we are using secondary data.

3.3. General Building Block (Online Water Quality Monitoring)

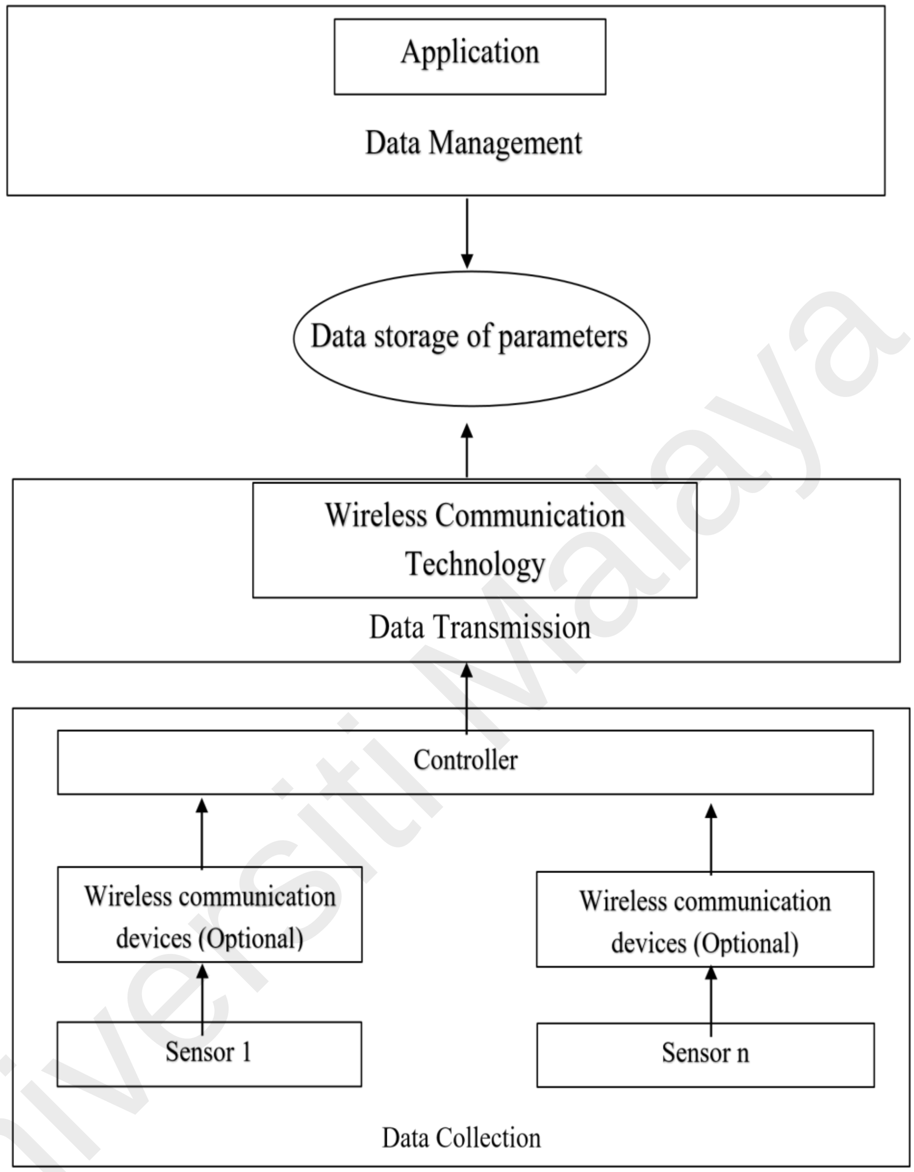

Figure 3.1: Smart water quality monitoring diagram

The smart water monitoring consisting of three main subsystems: data management, data transmission, and data collection. Each of the subsystems plays a vital role in the diagrams.

- Data management subsystems include any approach that allows access to the data storage cloud and can display the same to the end-user of the systems applications that have the access to data storage and able to display the same interface for the end-user.

- Data transmission subsystem will consist of wireless communication with add-on features such as an inbuilt security system that can transmit data from controller to cloud.
- Data collection subsystem involves multiple parameter sensors, including optional wireless devices that can transmit the sensors to the controller. Controllers can gather the data and processes at the same time.

Sensors are usually located at the bottom of the systems to monitor the water quality parameters. It needs to be placed in water, either running water or stored water. It can convert physical parameters to an electrical quantity that gives controllers input as optional communication devices. Controllers can read the data, process, and send the application using the best communication technology. The communication technology involved will be based on the application's needs to monitor. It will involve data management, data analysis, and alert systems.

3.4 Block diagram of the proposed system

The main parameters that will be monitored in the proposed systems are PH, water level, turbidity, and conductivity. The diagram of the proposed system can be understood such:

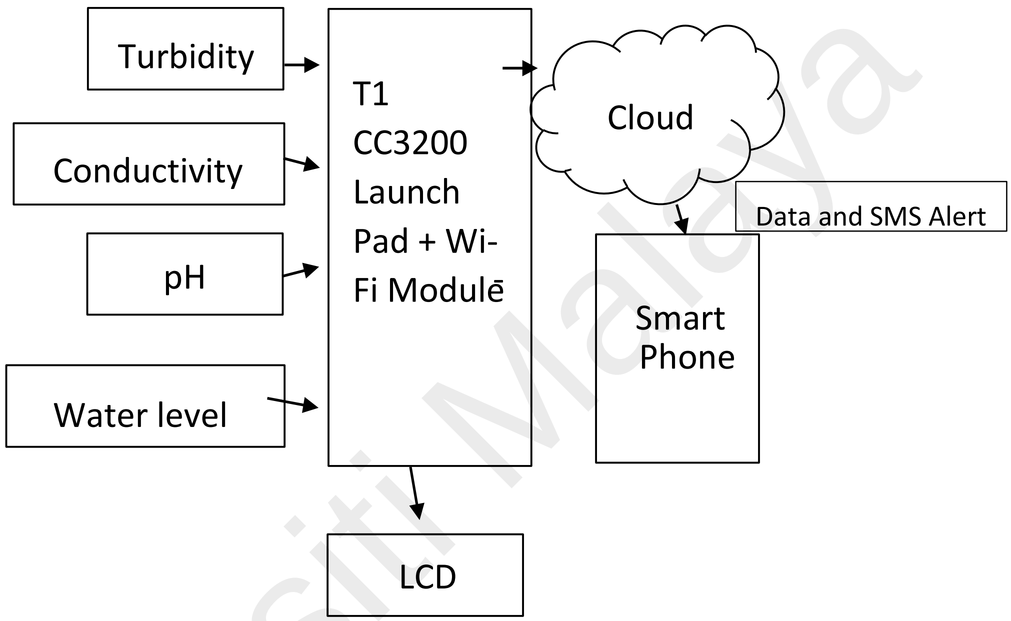

Figure 3.2: Block diagram of proposed system

A controller forms a central part of the IoT that enables water monitoring systems, but such a design is expensive, has high power consumption, and is more complex. A single-chip with a microcontroller with external Wi-Fi has been used for this proposed system, and it can connect to the nearest Wi-Fi hot spot for internet connectivity. Sensors are located directly interfaced with the controller. It monitors the parameters by placing the sensors into different solutions of water. It will appear in LCD, and the data from the sensors are sent to the cloud using the controller. The threshold value will be set according to the standards provided by the WHO. If the threshold value exceeds the standards, a message will be sent to the users mobile. A mobile application has been developed to view the values for each sensor in the cloud. This also will benefit the water quality monitoring authorities as well.

3.5 Proposed flowchart sensors

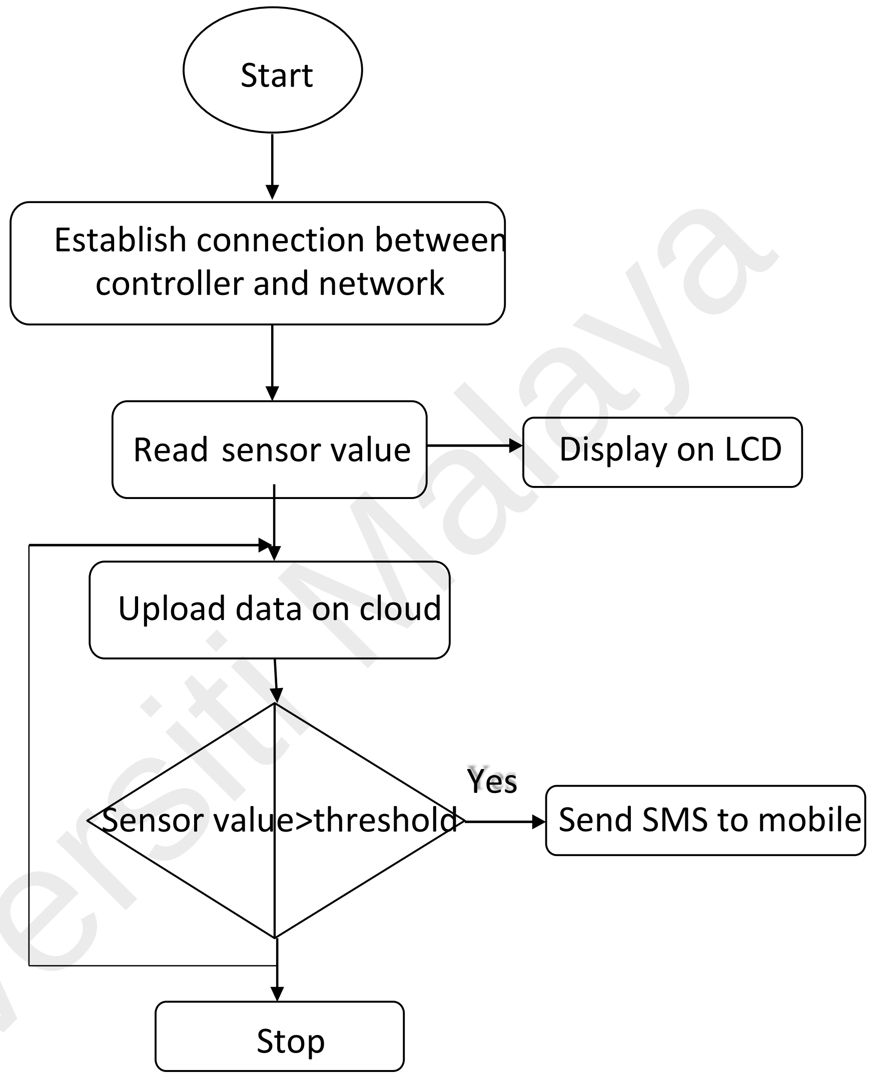

Figure 3.3: Flow chart of sensors data updating

The value that the sensors display will constantly updated in the cloud and displayed in the LCD, the flow chart for sensors data update in the cloud—programming implementation using ENERGIA IDE. Data transfer to the controller stored in cloud. The clouds offers a platform for developers to capture data and turn it into useful information. The features include a real-time dashboard to analyze data or control devices and share the data through public links. Data stored in the cloud can be used for detailed analysis. The cloud is programmed to send alert SMS messages whenever the monitored parameter exceeds the threshold limit.

Steps on how the systems are connected to the clouds:

1. Firstly, connect to the access point using SSID and password via phone or personal computer.

2. The controller is connected to the access point using the available Wi-Fi.

3. Token will be generated when login into the cloud platform.

4. The token id necessary in the program.

5. Data from the controller are loaded into the cloud.

6. Data can be viewed on the cloud platform

Continuous monitoring of water quality is necessary in helping to classify the water for its suitable application and meet to meet the standard for water consumption. Recently, with the significant progress in the Internet of Things (IoT), several IoT-based solutions have been devised to water monitoring. Commercial systems such as Canary and blue box can enhance the efficiency of the previous systems, but these systems are expensive, and the architecture is more complex to be implemented. Therefore, the implementation of these systems is limited to developed countries only. This has led to many studies to devise cheap and reliable IoT-based smart solutions for water monitoring. As an open research area of concern, several related reviews and surveys have been published to highlight progress in several areas such as sensor, wireless, communication technology, cloud services, computing devices, and others.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Proposed parameters to be a monitored in Malaysia

Each country has its national standards for water quality to ensure water quality remains free from contaminants that can jeopardize our health and cause the development of water-borne diseases. This standard also includes an industrial process in which the wastewater needs to be treated before being released into the water bodies to ensure water quality at an acceptable range. The parameter in water quality helps to identify whether water status is either polluted, clean, or needs immediate remedies. There are three main types of water quality parameters: biological, chemical, and physical parameters. Each of the types consists of different parameter indicators. According to the Department of Environment (DOE), National Water Quality Standards for Malaysia (NWQS) and Water Quality Index (WQI) has been used for the past 25 years as basic assessment for water quality. The parameters to be monitored in WQI are Ammoniacal Nitrogen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen, pH, and Total Suspended Solids (TSS), has been used to identify the presence of any contaminants. These six parameters have been used and implemented in the standard and regulations, but we are proposing other parameters to be more specific and detailed.

4.1.1 Taste and odor

Foreign matters such as organic and inorganic compounds or dissolved gasses can affect the taste and odor of water. It may come from other resources such as agriculture, domestic or natural sources. This method can be quantitatively by measure the volume of sample label A and dilute with the volume of sample B of an odor-free distilled water so that the results of the mixture can be detected at a total mixture volume of 200 ml.

It can be expressed in terms of threshold numbers as follows:

TON or TTN=(A+B)/ATON or TTN=A+B/AE (Eqn 1)

where TON is the threshold odor number, and TTN is the threshold taste number.

4.1.2 Color

Color can give an impression on the condition of the water bodies, and it can be due to material decays and other factors. Color can be measured by comparing the sample with standard color or color glass disks. It is understood that one color unit is equivalent to the color produced by one mg/L solution of platinum. The color sample can indicate as follows:

- True colors indicate measure after filtering all the suspended materials.
- Transparent colors indicate the entire water sample color consisting of both dissolved and suspended components.

Color graded on a scale of 0 (Pure water and colorless) -70 color unit

4.1.3 Bacterial Levels

Bacteria can reproduce rapidly under favorable conditions based on food supply, temperature, and PH. This rapid growth of visible colonies on the suitable nutrient medium can identify and count in the water. Most water-borne diseases are caused by bacteria such as cholera, fever, and others.

4.2 Proposed IT system for online water monitoring

The proposed IT system model for online monitoring systems uses the Internet of Things (IoT) to monitor real-time quality monitoring systems. It has involved several areas in terms of application, such as the application, types of sensors, communication technology implemented, and others. Implementation of IoT in online water monitoring can reduce the cost and introduce a less complex system built with Wi-Fi. It is capable of monitoring all the parameters on a real-time basis. It can notify the end-user immediately if there are changes or the water bodies have been contaminated. There are a few components and ideas that are important in the implementation of IoT systems, such as:

4.2.1 Communication technology

The wireless technology has been used to communicate between sensors, controller and data storage cloud. Each communication can use different technology and each technology has its frequency for information transfer.

4.2.2 Communication between sensors and controller

Example of types of sensors are the UART protocol and Zigbee. These sensors are usually connected to the controller. This technology has low energy consumption and has been designed for multichannel control systems. For online water monitoring, Zigbee protocols are used for communication between sensor nodes and controllers when the sensors are placed in a remote location away from the controller.

4.2.3 Communication between controller and data storage

The controller and centralized data storage communication is carried out using low-range communication standards such as the internet and 3G. The previous study highlighted the aim of alerting the user on the current water quality. It required an additional SIM card for the GPRS module connected to the controller. Recently, IoT and cloud computing usage have been vital in many applications (Alessio et al., 2016).

4.2.4 Controller used

A variety of type of controller has been used in previous studies for online water monitoring, and each controller has its salient features. It works with GPRS and Wi-Fi modules for connectivity to data storage or others. An example of a controller that can be use such as TI CC3200 which include additional features such as Wi-Fi module and a dedicated ARM MCU for wireless purpose.

4.2.5 Sensors used

Several sensors can be used for online water monitoring (Niel et al., 2016). Some sensors have been fabricated in order to improve usability. A fabricated buoy-type sensor node is used for monitoring parameters; this includes a solar cell, Li-ion battery, power module, and transmissions module. Fabricated turbidity sensors are designed to be compatible with WSN technology, low cost, and accuracy.

4.2.6 Power Consumption

Power consumption is the major constraint in IoT applications as it needs power from batteries to operate. Communication of data is the main source of power consumption. Data communication for online water monitoring occurs in 2 stages from sensors and controller, and communication between controller and applications. The possible protocols for communication between sensors nodes and controller are Zigbee, Bluetooth, BLE, and LoRa. Wi-Fi is not suitable as it requires high power dissipation. Based on previous research, most researchers have been using Zigbee in their studies.

4.3 Key parameters in the proposed system

4.3.1 Conductivity

Measure the solution's ability to carry currents. This parameter helps in determining the salt contained in the water bodies. In this proposed design, two electrodes placed in the water potentials are generated, proportional to conductivity.

4.3.2 pH

To detect the properties of water, either acidic, alkaline, or neutral, as each condition gives different explanations.

4.3.3 Turbidity

Measure cloudiness in the water bodies of the waterways.

4.3.4 Water level

Identify the water depth in the tank; the probe method been applied to determine the water level. It can identify either high, low, or medium. It helps in detect the possible changes in water flow and can be an indicator to potential surface level flooding.

4.4 Location of water monitoring system

The outside curve of the stream is an excellent spot to do the monitoring, and the center of the main current is the perfect area to do the monitoring, avoiding the stagnant water and streambank in the main drafts.

The advance in portable sensors, communication, and computing technology has implemented in these systems, and it works as follows:

1. Embedded microprocessor-based gadget that can read specific water properties using portable sensors installed on site
2. Process acquired data locally is needed
3. Transfer data to the main station using wireless communication
4. Results update for the end-user, the local authorities, and consumers.

4.5 Sampling and frequency

Monitoring the water quality helps us to understand the water ecosystems and the impacts on humans and living organisms and, at the same time, ensure the water quality is according to the standards before being used and consumed by the people (Elisa et al.,2022). Studies and research have suggested better ways of monitoring water quality by the researcher. Implementation of high frequency in situ monitoring is widely employed in water quality monitoring schemes. It can reduce the cost associated with manual sampling, lessen the need for a workforce, and provide adequate time to process the sample than the traditional grab-sampling. High-frequency water quality models can reduce uncertainty, capture transient events, and reduce noise and power consumption. It can analyze events not captured by the traditional method, such as manual sampling and laboratory analysis. Furthermore, frequency components of time series are analyzed to understand the necessary sample needed for each water quality indicator.

Design monitoring networks can immediately provide real-time information on water quality and any water bodies' quality changes. Few factors need to be considered in design networks, such as the monitoring location, the water indicators, the frequency sampling, the technical resources, and any matters related to constraints such as cost, data collection, and handling, to design a program that can cover all-purpose of monitoring networks. Until the 21st century, water quality monitoring networks only relied on manual sampling and laboratory sampling for chemical and biological analysis (Strobl and Robillard, 2008). It provides ample information for long-term monitoring but is inconvenient for short-term trends and identification of rapid changes in parameters that are susceptible to the surrounding area and environmental influences.

Manual networks of monitoring depend highly on human interaction time. To obtain the results, it needs to transport the samples. There is a tendency to lose quality control potentially, and there is a time when it can affect your health and safety. Two technological advances can be implemented in order to overcome the disadvantages of manual sampling such as:

1. In situ sensors

   This sensor can provide a high-frequency measurement of a range of physical and chemical water quality parameters without highly depending on humans (Chen and Han, 2018)

2. In situ sensors and wireless sensors networks.

The ability to connect between these two sensors can significantly increase the amount of data observed and monitored real-time (Chen and Han, 2018).

This high frequency data able to support forecast models, compliance monitoring, and event-based on monitoring. It needs to be set up in advance and has limited flexibility in terms of its capabilities to respond to unexpected events at different locations. Frequency optimization can be applied using three different statistical approaches to determine the optimum sampling frequency for different water quality parameters. It also can be used to determine the minimum frequency required to communicate periodic fluctuations in water quality and investigate the additional benefit of recording data at a frequency higher than the minimum required.

4.5.1 Wireless Sensor Networks (WSN)

In recent decades, more technologies have been developed by the researcher, and one of them was wireless sensors in water quality monitoring. Most companies have deployed and implemented this technology to ensure their processes are according to the standards that the regulatory bodies have set. This sensor equips with data acquisition, transmission, storage, and redistributions.

Data acquisition- Network in situ using given sampling frequency and sensors probes can evolve on a broad range of physicochemical.

Transmission- The collected data is transferred to central technologies like GSM, ZigBee, or Wi-Fi. It can develop as IOT and able to gain more research attention. It only can be processed, stored, and analyzed once transferred.

Implementing these new technologies makes it possible for real-time monitoring and visualization of the parameter at fixed locations. The results are more accurate in describing the water bodies' quality and provide more freedom in selecting a frequency for monitoring water quality parameters.

4.5.2 Frequency for water quality monitoring network design

There are no correct ways of example or template for a design that can be used for design usually it based on a few considerations and factors such as definitions of the objectives of the system and capabilities to analyze the information gathered. The objective needs to be able to provide information that is important to water quality management. The consideration that needs attention is the type of water bodies and classification systems, the capabilities of existing networks, and pressure and risks on water bodies. The design of monitoring networks by selecting the variable to monitor or, the spatial arrangement and frequency measurements based on objectives (Strobl and Robillard, 2008). The quantitative design of water monitors is very challenging, the ability to define the sampling frequency is a key role in determining the efficiency of the network, data quality, and operation cost.

Definition of sampling frequency based on a few considerations such as:

Table 4.1: Consideration to address when define sampling frequency

Considerations	**Descriptions**
Purpose of WQMN	Compliance monitoring
Parameters time variable	Baseline characteristics
Technologies related capabilities	Building water quality forecasting models
Noise in dataset	Hourly patterns
	Daily patterns
	Seasonal Patterns
	Events based variabilities
	Data storage
	Data transfer
	Data handling

4.6 Recommendation to be considered in the design of online water monitoring.

1. Online Water Monitoring Sensors: The selection of appropriate sensors in online water monitoring is essential as it affects overall systems efficiency. A few factors that need to be considered are range, reliability, resolutions, and response time.

2. Sensors-Nodes: The function of the sensors node is to read sensor data, update the local display, and process and transfer data into the cloud via router or modem. It needs to be understood is the task is simple or too complex; different approaches of IoT cards need to be used to cater to the issues.

3. Gateway: Securing all parts of the concerned IoT is vital for it to function reliably. Online approaches always become a medium for cybercriminals to hack. It is essential to use IoT gateways. There are a few risks inherited in IoT devices from the manufacturer side such as insecure storage and data transfer, weak passwords, hardware issues, lack of secure update mechanism, and others.

4. Cloud IoT Servers: Custom development of cloud servers if feasible to minimize the risk. This is due to protecting data security from the third-party involvement as the risk of using public clouds IoT servers as part of the process that involves access and control of things, sensors data, and others.

4.7 Legislative approach to water quality management.

In Malaysia, the water resources are mainly from rivers, lakes, and groundwater. Rivers have become our primary and sole source for our consumption. The rapid shift in agriculture, urbanization, and industrialization have indirectly affected the river water bodies. Deteriorating the water quality in the rivers can deplete the resources and have severe repercussions for the counties and the future. The legislative approach is hoped to be able to counter the arising issues. Malaysia implemented its national policy based on the eight interrelated principles that highlight the sustainability of the water resources, conserve river vitality, and improve water quality. Effective policy outlines and strategies have been highlighted, consisting of multiple holistic approaches that can improve the rates of water bodies.

Then, the law has use as a standard outline in response to related incidents in regards to environmental problems in Malaysia; few laws has been highlighted before Environmental Quality Act come in force in 1974. 1929 Mining Enactment, 1930 water enactment, 1954 Drainage Works Ordinance, and 1974 Street, Drainage, and Building Act are some examples of laws that are largely use in sectoral, and it focused on specific areas. The subsidiary legislation of the Environmental Act 1972 is Environmental Quality (Prescribed Premises) Crude Oil, Raw Natural Rubbers, and Sewage and Industrial Effluents 1979. Any sources that threaten our water environment have been subjected to these regulations since 1970—it is an essential command and control approach utilizing effluents discharge standards. The effluent discharge on the upper streams is stricter than downstream. Additional legislation is in place to help and preventing the pollution into water bodies.

4.7.1 Prevention

Legislative approach in Malaysia are based on the Environmental Act 1974, Section 34A that requires reports on impact on the environment and it is mandatory. This includes all the prescribed activities and non-prescribed activities. It also requires written permissions to be obtained before any project starts.

4.7.2 Challenges

Few challenges need to be given into our consideration. The uniform discharge standard does not take into account in the assimilative capacity of the river bodies. There is compulsory to develop a standard for effluent discharge in the rivers or streams. Then, a number of sources is not complying with the existing discharge standard, and there is a necessity to review this standard to be in line with the international standard.

4.7.3 Institutional framework for water environmental governance

Table 4.2: Instutional Framework for Water Governance

Institution/Agency	Descriptions
Federal Government	
Eg: Ministry of water, land and natural resources, Ministry of science and technology, Environment and climate change, Ministry of health, Department of environment, department of irrigation, and drainage, Department of sewerage services, and other related ministries and agencies	Development of holistic water policy for country by setting policy directions. **Responsibility:** Policy matters
National water services commissions	Regulate the water services industry . **Responsibility:** Regulatory matters (Water services industry act 2006 as legal instruments

Table 4.2 Continued

Institution/Agency	Descriptions
National water council	Ensures coordination between federal government and various state governments in water planning and development **Responsibilities:** Water matters- Cross boundaries/ Inter- state/ issue on national interest
State Government	
Foresty Department. Town And Planning Department, Water Supply Department, Department Of Enviroment, State Water Regulatory Authorities And Other Related Agencies.	Regulate raw water abstraction, catchment management, enforcement **Responsibilities:** Raw water and land development matters

4.8. Advantages and challenges of implementation of Online Water Monitoring

The implementation of online water monitoring is one of the methodologies in mitigating the scarcity impact from industries and sectors that recklessly discharge the untreated water in the waterways, affecting the surrounding biodiversity. The benefits of online water monitoring are informative insight, instant alerts, and cost reduction (Sanjeev, 2021). Installing IoT in the monitoring systems that provide sensors-based monitoring that act as a sensor that fetches the water level data and transmits data to the user's dashboard. It offers prompt decision-making and necessary countermeasure. This can avoid any chances of spillage and detects consumption patterns, thefts, and leakages. Then, it is able to give an instant alert to end-user. All the data retrieving connects through advanced communication channels with the sensor-based systems. The system will notify on the water quality status; it later will be shared between the parties, and an instant alarm system will trigger and connect through the devices. Industries are able to benefit in terms of business productivity and quality.

Plus, it cost -efficient as integrating water authorities as online water monitoring can give a new perspective on the entire process of a water supply network. It can significantly cost savings on sensors, and running a maintenance schedule on time can reduce the downtime process. Implementation of IoT in water monitoring has encouraged people to connect using the internet to devices, increasing the dependency on online water monitoring. The systems need to be able to provide a user-friendly interface to monitor the water quality and take remedial measurements if required. The main challenges in online water monitoring are the cost, energy, and efficiency necessary for water distribution systems. The selection of water quality, quantity, and topography parameters is another challenge in online water monitoring.

4.9 **Generic roles and responsibilities for online monitoring**

Roles and responsibilities for every activity must be assigned to one or more individuals for the system. It should be aligned with the existing works function. The arrangement and approaches need to provide constant coverage to alert the system (EPA, 2019) . This include:

1. Training all workers from all shifts to alert on the monitoring system
2. Assign backup workers if the primary attending is unavailable
3. Cross-training on multiple responsibilities
4. Assign works to be on call for any emergency situations that need decision on the validity of the alert from the system.

Table 4.3: Generic roles and responsibilities

Role	Responsibilities
Water Quality Manager	- Decides the alert is valid (Possible contamination) - Facilitates communication - Receive alert
Water Quality Specialist	- Leads and assists based on historical data of water quality
System Operator	- Provides information when needed
Sensors Technician	- Provide information on recent sensors, maintenance, and determine whether the online monitoring system operating properly.

4.10 Application of online monitoring

The online water monitoring systems provide actual-time analysis of data collected and suggest the most suitable remedial measure to cater to the issues. It also provides early warning identification of the water quality hazards if it is contaminated. Each country has highlighted its standards and acceptable limits value of substances such as Ammonia, Iron, Zinc, and others in the water bodies that are safe to be consumed. The need of online water monitoring have been highlighted in the literature (Vijayakumar & Ramya, 2015; Niel et al., 2016). Smart water quality monitoring can be considered for lake and seawater used, for this application, distributed wireless sensors networks are required to monitor the parameters such as chlorophyll, dissolved oxygen, and temperature. In the research by (Xiuna et al., 2010), the researcher has suggested smart water monitoring in order to forecast the water quality based on the implementation of an artificial neural network in 3 years and the data has been transferred by using CDMA technology.

. The distribution system in water quality monitoring is challenging in the context of management of distributed wireless sensor networks. In (Ruan & Tang, 2011) solar enabled distributed WSN has been proposed for monitoring important parameters such as PH, turbidity, and oxygen density. Water at various sites can be monitored in a real-time basis by the implementation of composed solar cell enabler sensors and base stations. This application is more flexible, has low carbon emissions, and has less power consumption. A combined system using air and water quality measurement was proposed by (Mitar et al., 2016) by using additional sensors to measure humidity and air temperature.

4.11 Checklist On Online Water Monitoring

4.11.1 Establish goals

The overall purpose and decision data should be established before planning for online water monitoring. This purpose will create goals and guide monitoring implementation. These goals are important as it useful for the utility. The common goals of online water monitoring systems are to monitor the contamination accidents and to fully optimize the water quality system. It is important to monitor the water contamination as it can harm the community and the public. Contamination incidents can be unintentional and intentional. The goals of the systems detect and able to isolate affected areas and implement the corrective measure. There are several challenges in achieving design goals such as rapid detection needed for contaminants that are transient and occur over short period. Fully optimize the water systems required to avoid any issues such as nitrification, regrowth and disinfection byproduct formation.

4.11.2 Establish performance objectives

Performance objectives identify the capability of the system to operate within acceptable tolerances. This usually will include operational reliability, information reliability, and sustainability. Operational reliability will include the percentage of time online water monitoring system fully operational and the response time to correct problems in the system. While, information reliabilities is can be characterized as data quality objective that include data accuracy, data completeness, and identifications on false negative in the systems. Last, sustainability usually involves the cost to maintain online water monitoring system.

4.11.3 Review system resources

Review the resources prior and during helps in address the selected design goals. It keeps the existing flow and pressure meter records, records the previous water quality problems and any keep any complaint records.

4.11.4 Design online monitoring system

The design for online monitoring systems elements consists of monitoring locations, water quality parameters, monitoring stations, information management & analysis, and investigation & response procedure. The location needs to be based on the design goals of monitoring systems. It is usually ideal and location and able to determine particular goals. Selection of water parameters need to be relevant to achieve the goals. The information management system capable to generates alert and send the notifications when there is any water quality anomalies detected in the water bodies. When anomalies been detected, an alert investigation procedure need to be undertaken in identify the root cause of the problems.

4.12 Environmental benefits

Water pollution poses genuine impacts on the ecosystem, and suitable monitoring is vital in achieve sustainable growth by maintaining the health of the people and surroundings Ullo, S. L., & Sinha, G. R. (2020). In recent years, researcher to turn into online monitoring with the advance in Internet of Things (IoT) and new development of sensors. It is able to benefits the environment in many ways than traditional monitoring. The key components of environmental sustainability and progress of any country are based on few factors such as hazardous free environment, pollution few and clean nation. The implementation of online monitoring able to effectively address the challenges so that the environment is protected. With the recent advances in technology, it able to monitors factors that impact the environment in more precisely and it capabilities to control the pollution in the most optimal manners.

The wireless sensors networks act as an effective device for monitoring the temperature of water bodies and pollution control. The use of the Internet of Things (IoT), Artificial Intelligence (AI), and wireless networks are the example of modern technology use in environmental monitoring (Bhoomika K.N. et al, 2016). All these devices helped the monitoring system in address the challenges in multiple conditions. Online monitoring can be easily understood in cloud systems; it helps in identifying the water contaminated or clean since the devices embedded. The quality check can be done in the system as all the data is stored in the cloud and it can be use to forecast the water quality in the water bodies and ways to countermeasure the problem. These able to benefit the environment in the best ways.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Monitoring water quality is important not only for us but for the future used. There are many ways in monitoring the quality of water such as the implementation of the modern method or continuing to the conventional ways of monitoring is based on the end goals and the purpose of the studies. In Malaysia, we are still using manual water monitoring and there are only several stations for continuous monitoring available. This helps in monitoring our water quality and to notify the authorities on any anomalies in the water bodies but, with the implementation of online water monitoring in Malaysia we can actually be more effective and immediate response taken. In recent years, researchers been implemented several methods in online water monitoring in order to address the arising issues immediately to reduce and to avoid pollution in the areas. Internet of things (IOT), Artificial Intelligence (AI), and wireless sensors have been implemented in the online monitoring systems.

IoT is the best system implemented in online water monitoring and it one of the best practices for water monitoring as it develops more efficient, reliable and cost effective system with real time analysis in monitoring water quality. The involvement of several components in the systems such as sensor, data storage, controller, power consumption, communication technology, and others; this help the IoT systems work it best in the online water monitoring approach. Each communication uses different technologies and different frequencies to transfer information. There are several types of sensors, such as UART protocol and Zigbee. This sensor uses less energy consumption and can be used for multichannel control systems. This work is at its best in online monitoring as the sensors are located in a remote location away from the controller Next, the communication uses a standard range of communication such as internet and 3G lines. It required a sim card for the GRPS module connected to the controller. The types of controller used, such as TI CC3200, include additional features such as Wi-Fi and it dedicated for wireless purpose. This support the GPRS AND Wi-Fi Modules. Sensors such as fabricated buoy-type sensor node are used for monitoring parameters; this includes a solar cell, Li-ion battery, power module, and transmissions module. Fabricated turbidity sensors are designed to be compatible with WSN technology, low cost, and accuracy. In conclusion, power consumption in IoT applications is the major constraint as it needs power from batteries to operate

The parameter involved in online water monitoring are Ammoniacal Nitrogen to measure the amount of ammonia usually pollutants found in water, Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen needed by organisms to breakdown organic materials, Chemical Oxygen Demand (COD) to measure the oxygen need to oxidize soluble matters, Dissolved Oxygen to measure the volume life-sustaining oxygen in water bodies, PH for classification of water, and Total Suspended Solids (TSS) is solid that can be trapped in the filters. These parameters are important in determining the water quality in the water bodies is either clean or polluted and the corrective measure to be taken. There are also several methods that can be used in identifying chemical compounds in water such as the used of chromatography in detecting arsenic value in water bodies. The responsibilities to monitor water monitoring are spread among many federal, state, and local agencies. They are responsible for raw water development to the policy matter in regard to water monitoring. All agencies need to work together in order to keep water quality according to the national standards.

5.2 Recommendation for future studies

There are several recommendations for online water monitoring for future studies such as the use of sensors in the online monitoring systems is important as it alerts any anomalies in water, these sensors are expensive and their maintenance incurs more cost. It is installed deep in the water bodies and it is fixed, it can easily damage during a natural disaster. In the future, it hopes that there will be a technology that is able to keep sensors in good ways. Further, the systems and the software used for online monitoring systems need to be able to handle the large data set on water quality. As this historical data able to lead the authorities to forecast the water quality and can be evidence to proof the conditions of the water bodies. Some sophisticated apps is needed in the systems as it plays big part for the end user to understood on how the systems works and what can be done by individuals in monitoring the water quality providing the best system play vitals roles.

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