CHAPTER 1

Introduction and literature review

1.1 Water quality situation and health effects

Water is one of the important factors for the living and the demand of clean water has increased over time as a result of the world population growth. It has been predicted that the world population will grow by 40-50 percent approximately in the next 50 years. The demand of clean water has increased rapidly due to the development of industrial and urban growth which affected the environment as well [1]. In particular, the lack of potable water has become the major problem in any area. It was reported that 88 percent of 4 billion cases of diarrhea found all over the world were caused by unclean water, lack of hygiene and poor sanitation. Over 1.1 billion people are unable to access to clean drinking water. The contaminated drinking water was a major cause of approximately 1.8 million deaths, mainly in children younger than 5 years [2]. In addition, the United Nations (UN) has estimated that approximately 2.7 billion people will lack of clean water by 2025, which could lead to serious conflict [3,4].

In the recent year, the global water situation has become worse in Africa, Asia and Latin America. It was found that the rivers in those regions were the most polluted in the world thus it has been warned not to drink any local water directly. It was reported that bacteria from human excretion was found 3 times higher than the global average. It was also found that the lead concentration was of 20 times higher than those in the developed countries. In 2004, it was reported that, among the 7 main rivers in China, more than half of them were undrinkable as they contained toxic substances. It was also reported that the

Yangtze, the China's longest river, is "cancerous" due to industrial and agricultural pollutants. It is also found that the groundwater in Bangladesh is the most contaminated in the world (about 85 percent of groundwater has contaminated). The major contaminant is arsenic caused by soil sediments in the natural. Moreover, the water quality in the European rivers and lakes have been degraded by sewage, agricultural waste, industrial waste and chemicals, in which the USEPA has warned that the amount of waste in 2016 will be accumulated up to the super-polluted level of the 1970s [4].

Therefore, it is necessary and crucial to monitor the water quality for health benefits and public safety. This includes the use of water in agriculture, aquaculture and industrial. A good water quality monitoring will lead to the well organize and control of the activities in various systems in order to manage water efficiently and sustainably as much as possible.

1.2 Principles and theories of water quality change

Nowadays, there are many water quality monitoring methods used for different proposes. One is a laboratory test for water quality, this method could test for various parameters in water, some of which cannot be done by on-site test kits. However, a laboratory test requires many components such as specialist, well-trained technician, analytical instruments, sampling equipment, chemical for sample preservation and transportation. More importantly, a change in water quality during a transfer period is unavoidable. In order to minimize this change, a sample preservation process is crucial for this method. An alternative method is a mobile unit laboratory, which enable on-site water quality testing. A mobile unit equipped with analytical instruments could reduce the time for sampling and analysis processes. Although, it needs to be designed specifically to accommodate several units such as chemical storage, water purification system, power supply and safety system. This makes the analysis cost much more expensive than that of conventional laboratory method. The highly sensitive instruments also require special maintenance which would cost extra charges. Another method is a water quality monitoring station, which is equipped with sensors and modern devices allowing automatic and remote sensing. This method is useful for application in routine analysis and warning system. Nevertheless, it is highly expensive for development of new technology, installation and maintenance. In addition to aforementioned methods, several

advance technologies have been developed to assist monitoring and evaluation of water quality such as Geographic Information System (GIS) and Remote Sensing technology (RS).

Remote Sensing (RS) is the art, science and technology of observing an object, scene or phenomenon by instrument-based techniques, without physical contract with the object of interest. In modern usage, the term generally refers to the use of sensor technologies to detect and record emitted or reflected from an objects or a scene [28] or RS is the science and technology of acquiring information about the Earth's surface (land and ocean) and atmosphere using sensors onboard airborne or spaceborne platforms. The sensors are not in direct contract with the objects or events being observed [29]. Whom other definition of remote sensing would encompass vision, astronomy, space probes, most of medical imaging, nondestructive testing, sonar, observing the earth from a distance, as well as many other areas [30]. The remote sensing is based on electro-magnetic radiation which is reflected or emitted from an object is the usual source of remote sensing data. A device to detect the electro-magnetic radiation reflected or emitted from an object is called a "remote sensor" or "sensor". A vehicle to carry the sensor is called a "platform". Aircraft or satellites are used as platforms. The characteristics of an object can be determined, using reflected or emitted electro-magnetic radiation, from the object. That is, "each object has a unique and different characteristics of reflection or emission if the type of object or the environmental condition is different. Remote sensing is a technology to identify and understand the object or the environmental condition through the uniqueness of the reflection or emission [28, 29], concept is illustrated in figure 1.1. RS technology has been widely used to monitor the water resources and environment with large-scale, multi-spectral characteristics [32]. Vignolo [33] studied on water quality assessment using remote sensing techniques in Medrano Creek, Argentina by using satellite image from LANDSAT 7 ETM+ with two spectral bands [0.45 – 0.52 μm (blue), 0.52 – 0.60 μm (green)] to predict the water quality index.

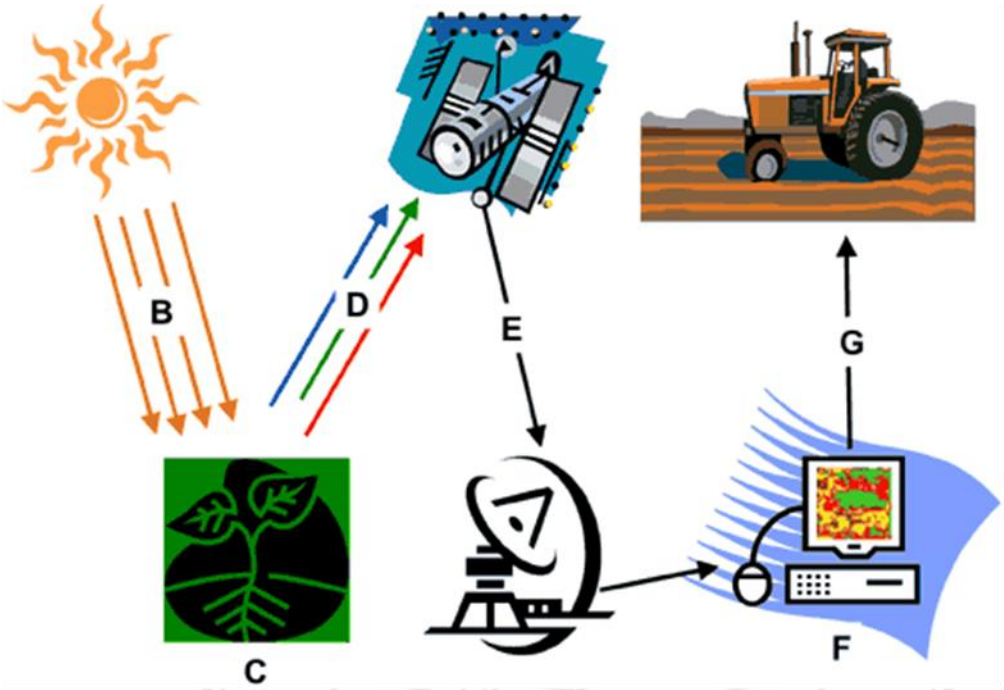

Figure 1.1 The remote sensing process [32]

Figure 1.1 illustrates examples of satellite remote sensing process as applied to agricultural monitoring processes. The sun (A) emits electromagnetic energy (B) to plants (C). A portion of the electromagnetic energy is transmitted through the leaves. The sensor on the satellite detects the reflected energy (D). The data is then transmitted to the ground station (E). The data is analyzed (F) and displayed on field maps, and then transferred to the farmer to provide information for land management (G) [31].

A geographic information system (GIS) is a computer-based system that provides the following four sets of capabilities to handle georeferenced data. (1) Data capture and preparation (2) Data management, including storage and maintenance (3) Data manipulation and analysis and (4) Data presentation [34]. Other definition by Environmental Systems Research Institute's (ESRI's) Dictionary of GIS Terminology, is a collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing and displaying all forms of geographically referenced information [35]. The processes of GIS consist of 3 steps. First, is to input data that identify and characterize each thematic layer from survey or digital map scanner. After that, data are converted to digital a map. Next, the data is processed analysis by algorithms condition following the aims. And finally, the information is reported (Figure 1.2). GIS has been widely used to determine the effect of land use/ land cover on nitrate pollution

[37] and studied water quality by using a GIS system for inorganic chemical species and results in maps of major factors affecting water quality [38]. McKinney and Cai [39] developed a GIS model for water resource management by linking GIS and a water resource management model. Shaban [40] studied water source and water pollution from agricultural drainage water. They used GIS decision support system for decision making in managing and controlling pollution. Kistemann [41] applied GIS to study the relationship between water quality and health in less developed counties.

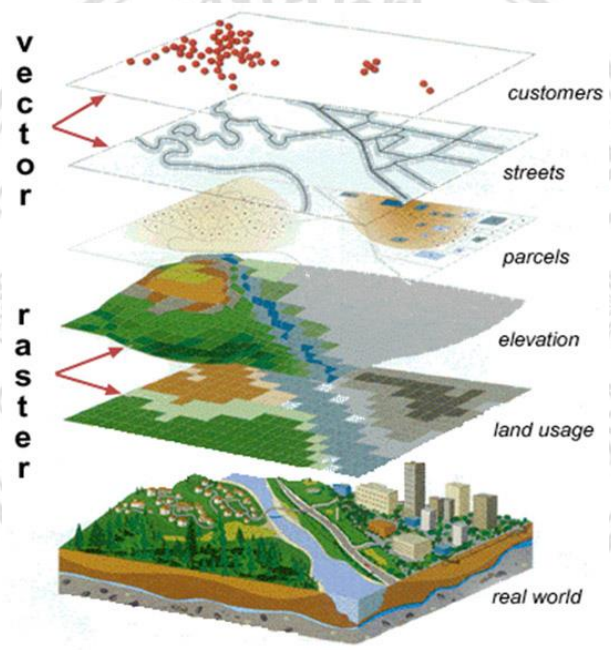

Figure 1.2 The layer information of GIS [36]

1.3 Parameters selection for the study

The importance of parameters and reasons of selection in this study. An accuracy in assessment of water quality depends upon the number of the monitoring parameter. The greater number of parameters are used, the more accurate the water quality results is. However, there always are the limitations of the equipment, time and budget, thus only some parameters associated with the point source (Table 1) or parameters important as an indicator of water quality (Table 2) were chosen. There are 18 frequently used parameters for water quality evaluation; Temperature, pH, Alkalinity, Turbidity, Total Solid, Suspended Solid, Total Dissolved Solid, Conductivity, DO, BOD5, Total Organic Compound, Ammonia, Nitrogen, Phosphorus, Toxics, Fecal Coliform Bacteria and Total

Coliform Bacteria.

In this study, only 10 important parameters were selected as follows; pH, Temperature, DO, Conductivity, TDS, Turbidity, Ammonium, Nitrate, Phosphate and COD. Some of these parameters are related to other parameters, for example, a high concentration of ammonium which is generally produced by human activity could related to the number of contaminated fecal coliform bacteria. The amount of organic compound in water was measured using COD instead of BOD due to the limitation of the BOD method.

Table 1.1 Sources and associated pollutants [45]

Source	**Common Associated Chemical Pollutants**
Cropland	Turbidity, phosphorus, nitrates, temperature, total solids
Forestry harvest	Turbidity, temperature, total solids
Grazing land	Fecal bacteria, turbidity, phosphorus, nitrates, temperature
Industrial discharge	Temperature, conductivity, total solids, toxics, pH
Mining	pH, alkalinity, total dissolved solids
Septic systems	Fecal bacteria (i.e., Escherichia coli, enterococcis), nitrates, phosphorus, dissolved oxygen/biochemical oxygen demand, conductivity, temperature
Sewage treatment plants	Dissolved oxygen and biochemical oxygen demand, turbidity, conductivity, phosphorus, nitrates, fecal bacteria, temperature, total solids, pH
Construction	Turbidity, temperature, dissolved oxygen and biochemical oxygen demand, total solids, and toxics
Urban runoff	Turbidity, phosphorus, nitrates, temperature, conductivity, dissolved oxygen and biochemical oxygen demand

Table 1.2 Water Quality Index and Parameters

Water Quality Index (WQI)	Parameters
simplified WQI (ISQA)	Temperature, Total Organic Carbon, Suspended solids, DO, Conductivity
Pesce and Wunderlin'sWQI	DO, Conductivity, Turbidity
Liou's river-pollution index	DO, BOD_5, Suspended solids, Ammonia nitrogen
NSF WQI	DO, Fecal Coliforms, pH, BOD_5, Nitrate, Phosphate, Temperature, Turbidity, Total solid
OIP (Overall Index of Pollution)	Turbidity, pH, Color, DO, BOD, TDS, Hardness, Cl, SO_4, NO_3, Total Coliform, As, F

Adapted from M.Terrado [46] and A. Sargaonkar [47]

The 10 parameters used in this study have their characteristics and important properties as follows;

1.3.1 pH

pH is an indicator of aquatic life in the water. Such fish can live in the pH 5.0-9.0 (optimum range is 6.5-8.5). It is also a key factor that controls the reaction process. For example, the solubility of nutrients, heavy metals and toxicity of ammonia in the water bodies.

1.3.2 Temperature

Temperature is an important controlling factor of many activities in water bodies. A changes in water temperature will affect microorganism such as plankton and bacterial species. In addition, the temperature is a major factor that effects the chemical composition of substances, for example, charge of ammonia ion and dissolved oxygen in water.

1.3.3 Dissolved Oxygen (DO)

DO is essential for aquatic life in the water. A low DO (less than 2mg / L) makes aquatic life hard to breathe and become stress. The controlling factors of DO are based on atmospheric pressure, temperature and salinity. DO can be measured in terms of % dissolved oxygen saturation.

1.3.4 Conductivity

Conductivity is an indicator of the number of ions in the water, which is often caused by a group of compounds from salt leaching or industrial waste drainage. In addition, conductivity are also affected by the changes in temperature.

1.3.5 Total Dissolved Solid (TDS)

In natural water sources, total dissolved solids are composed of organic salt and dissolved material. For the amount of polar compounds, TDS could be in a relation to the conductivity. For non-polar compounds such as soluble sugars, TDS may indicate a relationship to the amount of dissolved organic matter such as COD or BOD.

1.3.6 Turbidity

Turbidity in water may have many factors, including organic compounds, inorganic and microorganism like algae. The organic matter may cause a low DO from the bacterial decomposition of organic matter. On the other hand, the inorganic suspensions may obstruct the respiration of aquatic animals and may prevent the sun light shining down to the bottom of water body and block photosynthesis. The turbidity from microorganism like algae may indicate high level of nutrients in the water causing algae bloom phenomenon.

1.3.7 Ammonium

Ammonia (NH_3) and ammonium ion (NH_4^+) both can be found in water, depending on pH. In this study, the method for determination of both spices was chosen. Ammonium is an indicator of contamination caused by domestic waste or wastewater treatment plant. If high concentration of ammonium was under optimum pH and temperature conditions, it could be transformed into a toxic form which is harmful to the aquarium.

1.3.8 Nitrate

Nitrate in the water bodies may be caused by many factors, for example, dissolved minerals, agricultural runoff and leaching of fertilizer and nutrients into the water. Also, it could be a result of the transformation of ammonia via the bacterial process. Normally, nitrate is not directly harmful to aquatic life in the water, but it could

cause the phenomenon of algae bloom when combined with phosphate.

1.3.9 Phosphate

Phosphate is a compound of phosphorus, naturally found in plants, animal waste, fertilizers in agricultural areas, sewage and domestic wastewater treatment. Phosphate in water body could be transformed into an available form for plant intake. If it combined with appropriate amount of nitrate, it can cause an algae bloom phenomenon.

1.3.10 Chemical Oxygen Demand (COD)

COD is an indicator of the amount of organic matter in water. If it is too high in water, it can promote bacteria grown rapidly causing low DO and effect on the animals lives in water. Generally, the value of BOD was measured, but COD was chosen in this study due to relatively rapid measurement.

In order to measuring and monitoring the results at sampling site immediately, including the interpretation of the environment, planning, monitoring and problem solving, the appropriate equipment and methods of monitoring were used. The Digital Probe Meters were used for measurement of pH, Temperature, DO, Conductivity, TDS and Turbidity. The Test Kits were used for determination of Ammonium, Nitrate, Phosphate and COD.

1.4 Modern information technology

Today, modern IT has been developed rapidly and has become multi-tasking, so it has been employed in various fields of researches. It could offer cost-effectiveness, safety and environmental-friendliness. In this study, modern IT has been applied for water quality monitoring including hardware, software and mobile application.

Hardware has currently developed to be small with multi-function. For example, a Smartphone, apart from voice communicate, has many functions like locate geographic coordinates, navigation and internet connectivity, etc. [48]. Software and Application have been developed to offer free version, user-friendly, easily accessible with a Cloud Storage, Cloud Computing and Security. It can also support for many OS like the Google Service.

Google Maps is an on-line map technology provided by Google and can be used for all operating systems. It is multi-function application such as the navigation on a Smart Phone, virtual simulation (3D Map) to explore public services, etc. It also enables user to create on-line maps and add Text, Photo and VDO to a map as well [50, 51, 52].

Google Earth is a virtual globe program that simulates the geographic information. It can be used like Google Maps [53, 54]. It also offers Google Street View showing a panorama view of many places.

Google Drive is a Cloud storage provided by Google service for free on a limited volume. A user can store any format of data and share information at anywhere and anytime. In addition, Google has also included the services of Google Docs, the application for document management either online and offline such as documents, spreadsheets, presentations, drawings, forms, etc. Some application also can work on the Cloud computing system [55, 56].

Google Sites is a Google service that allows users to create their own Website or Webpage [57] for a presentation and sharing information [58].

Picasa Web Albums (PWA) is a service that Google provides a limited space to store data (photos and VDO) for free. A user can share information it others in the Cloud Storage [59, 60].

Moreover, there are several software and applications for communication and remote control widely-available, which can be employed in the study. For example,

Skype is used for communication in the form of text, voice and video, which can run on both a computer and a smartphone [61].

TeamViewer is an application for remote control on a computer and a smartphone. It can be used to transfer data and/or share information. Currently, it supports many operating systems [62].

LINE and Viber are applications for sharing information in Text, graphics, video, audio media and conversation. It can run on both a computer and a smart phone [63, 64].

WhatsApp Messenger is an application for text message. Currently, it can run on some operating systems as iPhone, BlackBerry, Android, Windows Phone and Nokia [65].

Google application has been developed and applied to use in various fields as the following.

Santos [66] made use of modern IT with user-friendly web-based spatial decision support called “Google map” for multiple vehicle routing.

Yang [67] evaluated images from Google Earth to study population distribution that can extract man-made building features from the image reasonably, which can then serve as the basis for the preliminary mapping of rural population distribution. This may prove to be promising alternative for deriving spatial datasets on rural population distribution in many parts of the world.

Vries [68] development of Google Maps as a tool to identify points of interest and valuable. This is necessary both to assess the environmental impact and cost analysis.

Choi and Nieto [69] development of software by applied Google Earth as a tool to analyze and choose the best route to transport the mine that saving time and fuel.

Wang [70] chose Google Maps / Earth to develop a meteorological model together with Software Java script and animation display.

Wilbers [71] study of surface water quality in the Mekong Delta of Vietnam and show pollution point on Google Maps.

1.5 Development and apply modern information technology to water quality monitoring

The current water quality monitoring methods are limited due to a change in the sample during sample transportation, the automatic monitoring stations could only detect some parameters using digital probe meter [28], and the mobile unit was more expensive and difficult to maintain. In addition, the method of the modern IT RS and GIS for the water quality monitor could only be developed and used by specialists. The data collection and processing may take several days. Therefore, it is interesting to present Modern IT application and development of a system for monitoring water quality.

Today, Modern IT technology has been advanced and people has been familiar with using applications for many proposes, such as entertainment, communication, business, and learning. Google service, a popular free application, has been proposed for use in

water quality monitoring in this study. It has never been reported for this propose yet. Many applications could be used together with a single login such as Google Maps, Google Docs, Google Drive, Google Site, Google Picasa Web Album and so on. In addition, it has security check which will report immediately if an unfamiliar IP address has been found. All product of Google service can be presented and shared to the public on a website by Google Site from anywhere and anytime. This should be useful for real time monitoring of water quality [72].

Many Modern IT hardware could also be used in the system such as Computer Notebook, Digital Camera, GPS Navigator and Smart Phone. Today, these devices have been developed to be smaller, easy to use, and multi-function, especially smartphone. Most smartphones have Built-In Camera, GPS and Memory for data storage. In addition, it can connect to the Internet and share it with other devices. From these advantages, it will be useful for water quality monitoring such as take a photo to record the measurements. A photo will contain details like date, geographic coordinates and device property, making the data traceable. Also, a portable battery backup will enable working continually throughout the day. Moreover, Google Service can work on Smart Phone, it can run on Cloud Storage and Cloud Computing both Online and Offline. (The system will automatically update information for Picasa Web Album, Google Docs and Google Drive whenever the Internet is available). This makes the system more flexible for use.

In addition, other free software and applications available in all platforms like Skype, TeamViewer, Line, Viber and WhatApp can be used to communicate between the center lab and the on-site monitoring team. The monitoring team can share information and visual images at the sampling site to the center lab in real-time. This will help reduce operation time and costs significantly.

Thus, it has been of interest to make use of Modern IT to develop a system for water quality monitoring. The Smart Phone, Digital Camera, GPS Navigator and Computer Notebook can be used to manage information of water quality. Together with chosen methods for quick measurement, this is possible to display the result in real time or semi real time to the public on the website (Google site). The website could display a map of the sampling linked from Google Maps, information of measurement linked from Picasa Web Album. Google Drive will be used for storage files any format, including VDO clip

and Google Docs will be used to store and display measurement results both in number value and graph. This new method employing modern IT will serve as the cost-effective system for water quality monitoring.

1.6 Aims of the studies

The aims of this thesis is to develop the water quality monitoring system including:

1.6.1 To develop the system of water quality monitoring employing modern information technology with analysis method for rapid measurement and real-time data display.

1.6.2 To demonstrate the system for water quality monitoring at Chiang Mai Moat, as a model study for still water.

1.6.3 To demonstrate the system for water quality monitoring at Mae Ping River passing through Chiang Mai city, as a model study for running water.

1.6.4 To demonstrate the system for water quality monitoring at Phayao Lake, Phayao province, as a model study for still water and running water.

1.6.5 To demonstrate the system for water quality monitoring in specific event, big flooding of Thailand 2011-2012, as a case study with still water and running water.