UNIVERSITI PUTRA MALAYSIA

OPTICAL TRANSMISSION-BASED WATER TURBIDITY MEASUREMENT SYSTEM

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

April 2006

DEDICATION

Special dedication goes to my beloved mother and father who have been very motivating and supportive towards my achievement for success in life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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April 2006

Chairman: Rahman bin Wagiran

Faculty: Engineering

Turbidity is one of the important parameter for the determination of water quality. The current existing method of measuring turbidity of water could come in bulky size or small portable turbidity meter. The ability to handle many samples and implementation of on-line monitoring is limited for such devices while some do not support this feature. Taking measurements would be laborious and time consuming especially when the sources of samples are located in remote places which are difficult to be accessed by human.

In this research, an alternative turbidity measurement system called the "Optical Transmission-Based Water Turbidity Measurement System" is designed and its performance is analysed and compared to the measurement from a standard turbidity meter. The concept of the proposed measurement system is to make the turbidity measurement remote, easy to handle and more flexible. The use of fibre optic as the element of carrying light enables measurement taken at the source of sample but could be remotely controlled from other place by the user. The design for the fibre optic set-up, transmitter circuit, receiver circuit and signal conditioning circuit were

covered. The assembly program for Peripheral Interface Controller (PIC) was also created.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

SISTEM PENGUKURAN KEKERUHAN AIR MENGGUNAKAN KONSEP TRANSMISI OPTIK

Oleh

RUHIZAN LIZA BINTI AHMAD SHAURI

April 2006

Pengerusi: **Rahman bin Wagiran**

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Kekeruhan air adalah satu daripada ciri penting yang terdapat di dalam pengukuran kualiti air. Kaedah yang digunapakai kini boleh didapati daripada saiz mesin yang besar sehingga saiz yang kecil dan mudah dibawa dipanggil meter pengukur kekeruhan. Bagaimanapun, pengukuran yang melibatkan sampel yang banyak dan aplikasi untuk pemerhatian secara berterusan adalah terhad. Penggunaan kaedah sedemikian juga memenatkan dan menggunakan masa yang lama terutama bagi pengukuran sampel yang berpunca daripada kawasan pedalaman dan sukar dilalui oleh manusia.

Projek ini adalah bagi menghasilkan satu sistem pengukuran alternatif bagi mengukur kekeruhan air yang dinamakan "Sistem Pengukuran Kekeruhan Air Menggunakan Konsep Transmisi Optik". Setelah direka dan diuji, hasil pengukuran dianalisis dan dibandingkan dengan pengukuran daripada satu alat meter pengukur kekeruhan. Sistem ini boleh menghasilkan satu kaedah pengukuran yang mudah, lebih fleksibel dan boleh dikawal daripada tempat pengguna alat tersebut dari jauh melalui aplikasi gentian optik yang digunakan untuk membawa cahaya. Projek ini

meliputi pemasangan gentian optik, pembinaan litar untuk pemancar, penerima cahaya dan pembaik signal. Selain itu, satu program untuk operasi sebuah pengawal yang dipanggil "Pengawal Antara Muka Persisian" atau PIC juga dihasilkan.

ACKNOWLEDGEMENTS

In the name of God, Most Gracious, Most Merciful. Praise be to God, the Cherisher and Sustainer of the Worlds; Most Gracious, Most Merciful; Master of the Day of Judgment. Thee do we worship, and Thine aid we seek. Show us the straight way, the way of those on whom Thou hast bestowed Thy Grace, those whose (portion) is not wrath, and who go not astray. May His blessings and peace upon our master Muhammad, the Truthful and Trustworthy, and upon his family, and companions, and all those excel in the following them until the day of reckoning.

I am deeply indebted to my supervisor, En. Rahman Wagiran and the committee members, Dr. Samsul Bahari Mohd Noor and Dr. Roslina Mohd Sidek for their helpful suggestions and comments during the progress of the thesis. My sincere gratitude also goes to my friends and the laboratory assistants who have assisted me throughout the finishing of this project.

Last but not least, I am deeply grateful to my mother and family for their encouragement, understanding, and support for the success of this project.

I certify that an Examination Committee has met on 13th April 2006 to conduct the final examination of Ruhizan Liza Binti Ahmad Shauri on her Master of Science thesis entitled "Optical Transmission-Based Water Turbidity Measurement System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

RUHIZAN LIZA BINTI AHMAD SHAURI

Date:

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LIST OF ABBREVIATIONS/NOTATIONS/GLOSSARY OF TERMS

CMOS	Complimentary Metal Oxide Semiconductor
CPU	Central Processing Unit
EEPROM	Electrically Erasable Programmable Read Only Memory
I/O	Input/Output
LCD	Liquid Crystal Display
LED	Light Emitting Diode
NTU	Nephelometric Turbidity Unit
PIC	Peripheral Interface Controller
PPT	Parts per million
ROM	Read Only Memory
RAM	Random Access Memory
WDT	Watchdog Timer

CHAPTER 1

INTRODUCTION

The purpose of water quality measurement is to monitor specific parameters in bodies of water. Changes in these parameters may be harmful not only to humans but also to the organisms living in and around the water source. Although water covers more than 70% of the earth's surface, only a mere 1% of the earth's water is available as a source for drinking water [1]. Many factors can affect the quality of water in an ecosystem including ungoverned discharges of industrial or agricultural wastages such as asbestos, lead, mercury, turbidity and unstable organic chemicals, which often pollute and contaminate water supplies. This project focused on the measuring of one of the contaminant which is known as the turbidity. Turbidity of water is a measurement of water clarity to show how clear the water appears. The amount of total suspended solids (TSS) in water contributes proportionally to the value of turbidity. Insoluble particles impede the passage of light through water by scattering and absorbing the rays. Thus, the interference to the passage of light could be used for turbidity measurement using a turbidity index.

1.1 Objective of Project

In this particular project, the determination of good or bad water in terms of turbidity parameter will be studied. The current existing method of measuring turbidity of water utilizes a turbidity meter that could come in small portable or bulky sized ones. Thus, the ability to handle many samples and the implementation of on-line monitoring are limited in such cases. Taking measurement is laborious and time consuming especially when the sources of samples are located in remote places which are difficult to be accessed by human.

A turbidity measurement system with the application of optical fibre is constructed in this project. Comparison between the measurement from the proposed system and a standard method of measuring water turbidity is presented. The performance of proposed measurement system is analysed and data have been processed using PIC controller which gives the equivalent turbidity output on to the LCD, as water sample were measured. The research covered the design of fibre optic set-up, transmitter circuit, receiver circuit and signal conditioning circuit.

1.2 Thesis Structure

This thesis consisted of five chapters. Chapter 1 describes the importance of measuring water turbidity and the objectives of the project. It also explains the advantages of the proposed measurement system. The literature review of the concepts and also the theory of the components involved in the proposed system will be covered in Chapter 2. Followed by Chapter 3 in which details of the project methodology including the explanation on the setting-up of the completed system, on both the hardware and software for the controller, will be described. In Chapter 4, the results of the experiments and discussions are presented. Last but not least, the conclusion on the analysed results including the performance, problems encountered and future suggestions for the proposed system are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

Comprising over 70% of the earth's surface, water is undoubtedly the most precious natural resource that exists on the planet. Nowadays, human's drinking water has become greatly affected by not only industrial activities and fumes emitted by vehicles but also many other human activities such as agricultural and logging. It is important for everyone to understand the problem and study for ways to provide a solution to overcome the water pollution.

2.1 Water Pollution

Water pollution occurs when the quality of water is affected due to the addition of large amount of foreign particles to the water. When it is unfit for its intended use, water is considered polluted. Two types of water pollutants are point source and non-point source pollutants [2]. Point sources of pollution occur when harmful substances are emitted directly into a body of water. A non-point source delivers pollutants indirectly through environmental changes and contributes the majority of the contaminants in the current water system.

The major sources of water pollution can be classified as municipal, industrial, and agricultural [2]. Municipal water pollution consists of waste water from homes and commercial establishments. For many years, the main goal of treating municipal wastewater was simply to reduce the content of suspended solids, oxygen-demanding materials, dissolved inorganic compounds and harmful bacteria. However, the characteristics of industrial waste water differ considerably both within and among industries. The pollution effect of industrial discharges depends on biochemical oxygen demand, amount of suspended solids, the contents of specific inorganic and organic substances. Agriculture including the commercial livestock and poultry farming has become the source of many organic and inorganic pollutants in surface waters and groundwater. These contaminants include sediment from erosion of cropland, animal wastes and commercial fertilizers. Thus, the task of identifying the compound of a polluting substance is important for the attainment of practical treatment for the municipal wastewater.

2.2 Water Quality

Water quality can be defined as the measurement for the suitability of a particular water system for use by human, and its suitability for providing and sustaining a pollution-free environment [3]. A qualitative measure is important to determine and describe the condition of water i.e. to determine what substances are in the water and the concentration of each substance. A standard is used to determine the quality of a particular water supply.

The characteristics of water can be classified into two different parameters; the chemical and physical parameters. Chemical parameters are contributed by the solvent capabilities of certain particles in water [4]. This category consists of total dissolved solids (TDS), alkalinity, hardness, fluorides, metals, organics and nutrients. This parameter is not taken into consideration since the measurement of turbidity falls in the next physical parameter.

Physical parameters of water consist of suspended solids, turbidity, colour, taste, odour and etc. Solids in water may consist of both organic and inorganic particles which are classified by their size, state, chemical characteristics and size of distribution [4]. Organic material might come from plant fibres, bacteria etc. in surface water. Inorganic solids might come from clay, silt and other soil constituents in surface water. Other suspended materials come from human activities such as those included in everyday household discharge which also contributed to a variety of organic suspended impurities and inorganic suspended solids. Filtration is the most effective method on removing solids from water and in wastewater treatment, level of suspended solids (SS) is used to measure the quality of wastewater influent.

Quality of water could also be measured by its colour [4]. Water is often coloured by foreign substances such as organic particles encompassing from soils, minerals, aquatic organisms and etc. which are present in natural waters. Taste and odour also provide other methods for determining water quality. The taste and odour of water are very much depends on the combination of substances such as minerals, metals, constituents of wastewater and etc. [4]. In water treatment, water is oxidized using oxidants such as potassium permanganate and chlorine to remove the taste and odour.

2.2.1 Turbidity

Fluids can contain suspended solid matter consisting of particles of many different sizes. Some suspended material will be large and heavy enough to settle rapidly to the bottom of a container if a liquid sample is left to stand (the settleable solids) while very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid and the measurement of turbidity is a key test of water quality. [5].

Turbidity can also be defined by muddiness created by stirring up sediment or having foreign particles suspended [6]. It is a principal physical characteristic of water and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample [7]. This interference to light passage could be used for turbidity measurement using a turbidity index.

Turbidity of water shows how clear the water appears. The greater the amount of total suspended solids (TSS) in the water, the higher the turbidity value and vice versa [4]. In surface water, turbidity comes from rock fragments, silt, clay, metal oxides, micro-organisms and etc. Wastewater from household and industries are the common distributors for turbidity-producing materials such as detergents, soaps and emulsifying agents. Besides, particles in water may also consist of composites of heavy metals such as lead, mercury, and toxic contaminants. For human use, supplied drinking water has gone through great cost of water treatment. Low level of turbidity in long term is sufficient enough to give great effect to aquatic organisms and many researches are being done to avoid such treat to lakes and rivers [8].

The first practical attempts in the measurement of turbidity was in 1900 when Whipple and Jackson developed a standard suspension fluid using 1,000 parts per million (ppm) of diatomaceous earth (a non-toxic, safe substance made up from crushed fossils of freshwater organisms and marine life) in distilled water [9].

Dilution of this reference suspension resulted in a series of standard suspensions, which were then used to derive a ppm-silica scale for calibrating turbidimeters.

The Jackson candle turbidimeter, as shown in Figure 2.1, consists of a special candle and a flat-bottomed glass tube. A water sample is then poured into the tube until the visual image of the candle flame, as viewed from the top of the tube, is diffused to a uniform glow. When the intensity of the scattered light equals that of the transmitted light, the image disappears; the depth of the sample in the tube is read against the ppm-silica scale, and turbidity was measured in Jackson turbidity units (JTU). Standards were prepared from materials found in nature, such as Fuller's earth, kaolin, and bed sediment, making it difficult to achieve a consistent formulation for a standard data.

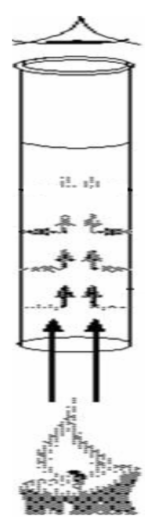

Figure 2.1: Jackson Candle Turbidimeter

In 1926, Kingsbury and Clark discovered formazin, which is formulated completely of traceable raw materials and drastically improved the consistency in standards formulation. Formazin is a suitable suspension for turbidity standards when prepared accurately by weighing and dissolving 5.00 grams of hydrazine sulfate and 50.0 grams of hexamethylenetetramine in one litre of distilled water. The solution develops a white hue after standing at 25 ºC for 48 hours. A new unit of turbidity measurement was adopted called formazin turbidity units (FTU) [9].

Finally, in 1970, turbidity measurement standards changed when the nephelometric turbidimeter, or nephelometer, was developed which determines turbidity by the light scattered at an angle of 90º from the incident beam. A 90º detection angle is considered to be the least sensitive to variations in particle size. Nephelometry has been adopted by standard methods as the preferred means for measuring turbidity because of the method's sensitivity, precision, and applicability over a wide range of particles size and concentration [9].

2.2.2 Importance of Turbidity

Clarity is important when producing drinking water for human consumption and in many manufacturing industries. Once considered as the most aesthetic characteristic of a drinking water, significant evidence existed, proving that turbidity control is also a competent safeguard against pathogens in drinking water [7], compared to clarity alone. Turbidity can provide food and shelter for pathogens and if not removed, turbidity can promote re-growth of pathogens in the distribution system. Although turbidity is not a direct indicator of health risk, numerous studies showed a strong