ALUM AND LIME DOSING CONTROLLERS FOR WATER TREATMENT PLANT

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Department of Electrical Engineering, University of Moratuwa
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degree of Master of Science

by

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DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

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Date: .11.02.2008...........

I endorse the declaration by the candidate.

UOM Verified Signature

Dr. Palitha Dassanayake

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Abstract

Many techniques are applied to the control of Alum and Lime commonly termed as coagulant dosing in a drinking water treatment plant. Coagulant dosing rate is non linear correlated to raw water parameters such as turbidity, conductivity, pH, temperature, etc. Manual method called Jar testing is used to decide the Alum and Lime dosage. However in practical situation, Jar testing is carried out maximum three times per day. But the parameters of water sources are continuously changing specially on rainy days. Therefore overdosing and underdosing of Alum and Lime are normally occurred. Excessive coagulant overdosing leads to increase treatment costs and human health problems, while underdosing leads to failure to meet the water quality targets and less efficient operation of the water treatment plant. It means that important requirement arises to automate the system with optimum coagulant dosage.

The research is aimed to propose an alternative to the jar test allowing for an on line determination of optimal coagulant dosage from raw water characteristics and design a system for feeding Alum and Lime automatically with a monitoring display.

The reasonable assumption made by this research is, except turbidity and pH value, other parameters are almost same throughout year. After analyzing thousand number of jar test results with corresponding turbidity values and pH value of incoming water, it was found turbidity value of raw water and the dosage of Alum has a relationship and pH value of raw water and the dosage of Lime has another relationship. Relationship of turbidity value of raw water and the dosage of Alum is second order polynomial. However pH value of raw water and the dosage of Lime have stepwise relationship. And also actual values of three hundred situations were taken and applied to check the validity of relationships and it is proved that the relationships which has obtained are well suited to develop the automation system.

Next objective is designing of hardware and software part of controller of an automotive system to dose Alum and Lime using the relationship. PIC16F876 microcontroller is selected as the controller; it made the task easier. Since PIC16F876 has 8-bit with analogue to digital converters, it handled analogue output of turbidity sensor and pH sensor. In this project MAX 7219 display driver IC could be easily interfaced with microcontroller by using three wires (SDO, SDI and SCLK) and LOAD (CE) which is common today named as Serial Peripheral Interface (SPI).The PIC16F876 chip is in electrical erasable packaged version (FLASH), and it helped for programming several times for testing our object before implementing.

Finally complete control and feeding system for Alum and Lime was designed. Value of turbidity was measured by a turbidity sensor. That value was taken to the microcontroller that decides the Alum dosage and changes the valve position using stepper motor accordingly. Either increment or decrement of the value of turbidity by 10 makes the changing of valve position in ADC. Either increment or decrement of the value of pH value by 0.1 makes the changing of valve position in LDC. Using MAX7219 IC current value of turbidity and current value of pH are displayed in ADC and LDC respectively.

Key features of the system are simple relationships constructed to find optimum coagulant dosage and ability of handling practical situations of water treatment plants using automation system with microcontrollers.

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My foremost duty is to express my sincere gratitude to my supervisor, Dr. Palitha Dassanayake, Senior Lecturer, University of Moratuwa, for his great insights, perspectives, guidance and sense of humor.

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Love and affection to my parents, Mr. and Mrs. Hettiarachchi, my husband, Chandana and my son, Ginura for their patience and understanding.

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List of Principal Symbols

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ANN	-	Artificial Neural Network
FRBS	-	Fuzzy Rule Based System
SCD	-	Streaming Current Detector
ADC	-	Alum Dosing Controller
LDC	-	Lime Dosing Controller
A/D	-	Analogue to Digital
SOM	-	Self Organizing Map
UEGO	-	Universal Exhaust Gas Oxygen
LCD	-	Liquid Crystal Display
USB	-	Universal Serial Bus
PLC	-	Programmable Logic Controllers
PIC	-	Programmable Intelligent Computer

Chapter 1

Introduction

1.1 Background

Water treatment costs five to ten rupees per cubic meter. However maintaining the standards of water quality is a must in water sector. Therefore it is very important to make standard quality of water at minimum cost. Automating systems in water treatment is a successful solution for fulfilling that requirement.

The water that is found in rivers and reservoirs are usually not suitable for drinking. The rivers and reservoirs are polluted by the activities of man and animals. The effluents of the industries situated along the water source, domestic wastes, storm water and sewage-all enter the water source through a system of drains and waterways.

The purification or the treatment process consists of five major steps. They are Aeration, Addition of chemicals, Sedimentation, Filtration, and Disinfection. Introducing Oxygen into water is called Aeration. By this means the taste, colour and odour causing substances and gasses are removed. Process of Addition of chemicals is also called a process of coagulation and flocculation. Lime and Alum are the chemicals used in water treatment. When chemicals are added to water, it reacts with soil and clay particles, microorganism and other substances. This is called coagulation. These particles associate with similar particles to form big flocs. The process is called flocculation. The flocs when it is heavy sink to the bottom. The result is clear water at the top. The third step is sedimentation. The flocs as stated above are formed in large sedimentation tanks. Clear water is found at the surface of the tank. This water is sent into the sand filters through network of channels. The suspended solids and some microorganisms are removed by filtration process. Disinfection is the last step. This is also called as chlorination as it uses chlorine gas to disinfect water. Chlorine is a strong oxidizing agent and it destroys pathogens- that are disease causing organisms like Bacteria remaining in the water.

After designing and constructing water treatment plant in proper way, main operational activity that affects water quality is adding of quantity of chemicals. Excessive amount of Alum/Lime dosing leads to public health matters and chemicals are very expensive since those chemicals are imported. Alum costs forty thousand rupees per metric ton and lime costs fifteen thousand per metric ton.

Less amount of coagulant dosing causes poor quality of water and decrement of efficiency of rest of stages of water treatment. Therefore it is very significant to dosing optimum amount of chemical.

Optimum amount of Alum/Lime is decided by a laboratory test called jar test. But this traditional method takes some time to give the readings. At that time parameters of water is changed. Therefore identification of a new method for deciding the optimum dosage is needed for automating the Alum/Lime feeding system.

After doing the jar test dosage is changed manually. Therefore this whole procedure relies on manual intervention. In this case, automating the system with suitable on line measurement can reduce manpower and chemical costs and improve compliance with treated water quality targets.

1.2 Problem Background

The water industry is facing increased pressure to produce higher quality treated water at a lower cost. The coagulation – flocculation process is a major step in the production of potable water, allowing the removal of colloidal particles. The main difficulty is to determine the optimum coagulant dosage related to the incoming water characteristics. Excessive coagulant overdosing leads increased treatment costs and public health concerns, while underdosing leads to failure to meet the water quality targets and less efficient operation of the water treatment plant.

For the moment manual method called jar testing is available to predict optimum coagulant dosage rate. Jar testing involves taking raw water sample and applying different quantities of coagulant to each sample. After a short period of time each sample is assessed for water quality and the dosage that produces the optimal result is used as set point. Operators change the dose and make a new jar test if the quality of treated water changes.

Disadvantages associated with jar testing are the necessity to perform manual intervention, and lack of adaptation to abrupt changes of water characteristics.

After getting the jar test results manual controlling system is used to change the dosage. Therefore whole procedure is done by manual control and it leads to wastage of expensive chemicals, failure to meet water quality targets and reduced efficiency of sedimentation and filtration processes.

1.3 Research Objective

The main objectives of this research is to propose an alternative to the jar test allowing for an on line determination of optimal coagulant dosage from raw water characteristics and design a system for feeding Alum and Lime automatically with a monitoring display.

1.4 Organization of Dissertation

This report consists of five chapters. The first chapter discusses the background of the study, shape of the problem and goals which are going to achieve. The second chapter is the literature review. It consists of historical review of coagulant dosage controllers in water treatment plants and presents the state of the situation.

In chapter three under research design and methodology, it has discussed method of data collection and method of pull off configuration of the system, layout diagrams and components of the system. The chapter four is discussing the research findings. It includes equations for optimum Alum and Lime dosage and system algorithm, software and hardware developed.

The final chapter which is chapter five discussed the conclusions and recommendations.

The report ends with References and Appendices.

Chapter 2

Literature Review

Alum and lime dosing controlling in water treatment plants is a developing area. In Sri Lanka context, dearth of literature can be readily retrieved. However experimentations and projects are done and ongoing worldwide to some extent.

This chapter presents literature on Alum and Lime dosing controlling in water treatment plants, microcontroller based systems, water quality parameters, jar test in to water treatment process, covering wide range of text books, journal articles, thesis reports, reputed websites and etc.

2.1 Historical Review

Studies were carried out related to Alum and Lime (coagulant) dosing controlling in water treatment plants and followings describes about them.

Various types of intelligent methods used in dosing control of water treatment are one of a study area popular in water sector.

In a research article by Juuso et al., (2003), was addressed the Linguistic equations method, an intelligent method using to define new operating point of chemical dosing according to the quality or amount of incoming water. In this paper data were recorded from a real water purification process and two kinds of models were derived for the process by using this information, namely steady state and a dynamic model. Static model defines the new operating point and the dynamic model predicts a reasonable dosing rate for the chemicals in the current working point. They also stated that linguistic equation helped them handled quite small data since linguistic equation do not necessarily need expert knowledge unlike fuzzy systems and do not have to be as large as for neural network. They concluded that dynamic model needs improvement before using it in the controller design.

An integrated coagulant dosing system based on unsupervised and supervised neural network models, as well as various statistical techniques are introduced in the research done by Valentin et al., (2000). The system developed includes raw water validation and reconstructed based on a Kohonen self-organizing feature map, and prediction of coagulant dosage using multilayer perception. The performance of the network was dependent on the quality and completeness of data provided for system training. Also they stated that continuous updating of training data would certainly improve the performance of the system.

Valentin and Denoeux's (2002) research was focused on a neural network – based software sensor for coagulation control in a water treatment plant. It described the application of artificial neural network techniques to coagulation control in drinking water treatment plants. The software sensor developed was a hybrid system including a self-organizing map (SOM) for sensor data validation and missing data reconstruction, and a multi-layer perception (MLP) the coagulation process. They also stated that this system can handled various sources of uncertainty such as atypical input data, measurement errors and limited information content of the training set.

In the research article by Baxter et al., (2002) was discussed a methodology for developing with a handful of time and successful ANN models of drinking water treatment process. They presented that the ANN modeling methodology allows utilities to develop multiple – variable nonlinear models of complex unit processes such as coagulant dosing control in a simple sequential fashion. Their conclusion was, ANN modeling methodology allowed utilities to develop multiple variable nonlinear models of complex unit processes in a simple sequential fashion and with improved usability. And they also stated that ANN technology will play a larger role in helping utilities meet customer and regulatory demands on finished water quality through improved modeling in future.

Project Report, Delft 2000 was reviewed the principles of various types and architectures of neural network and fuzzy adaptive systems and their applications to integrated water resources for management. It concluded that fuzzy-based methods are applied for identifying optimal control action of wastewater treatment plant, determining optimal dosage thereof and determining leakage. Combination of expert knowledge was also applied. Fuzzy rule based systems (capable of building rules automatically) had been applied for determining optimal control action and filling in the measured data.

In the research article done by Masson et al., (1999) was addressed another software sensor design, based on empirical data ecological modeling and it stated that process monitoring and control in water treatment relies heavily on accurate and reliable sensor information. Whereas many process parameters can be measured continuously using relatively simple and cheap physical sensors, the determination of certain quantities of interest requires costly laboratory analysis which cannot be performed on-line. They also stated that such high level information could be inferred from available measurements of observable quantities using a statistical model called as software sensor.

Both research article done by Mirsepassi et al., (1995) and Evans et al., (1998) were addressed the potential effectiveness of an approach of building a software sensor for on-line determination of optimal coagulant dosage from raw water characteristics such as turbidity, pH. conductivity, etc., based on artificial neural network.

Studies done by Bernazeau et al., (1992) and Dental (1995) emerged an automatic device called a streaming current detector (SCD) in coagulation monitoring and control. This device was based on the measurement of the net residual charge surrounding turbidity and colloidal particles in water. It required a set point to be entered, assumed to represent an optimum water quality standard. Streaming current values above the set point indicated an excess of coagulant, while values below the set point indicated insufficient coagulant dosage for full flocculation to occur. A jar test needs to be carried out to determine the set point. They also stated that this method is costly and limited efficiency for certain types of raw water quality.

In the research article done by Trautmann and Denoeux (1995) was addressed applications of self organizing maps (SOM's) to water quality monitoring. The SOM model combined the goals of projection and clustering algorithms and might be seen as a method for automatically arranging high – dimensional data. It used at the same time to visualize the clusters in a data set , and to represent the data on a two dimensional map in a manner that preserves the non linear relations of the data items, nearby items being mapped to neighboring position on the map.

Studies on coagulant control and optimization done by Lind, (1994) were focused on both manual and automatic methods to predict optimum coagulant dosage rate.

The article written by Pask, (1993) has illustrated budget saving of selecting optimum chemical dosage in water treatment by jar test. According to that for accurate jar test it took minimum one and half hours.

Chazel's (2006) research on controlling oxygen sensors with an automotive microcontroller had addressed the feasibility of controlling a UEGO sensor directly from a microcontroller, with a low level of cost and complexity. The use of a microcontroller was particularly adequate for this application. He also stated that the two regulation loops were easily implemented on the microcontroller and interfaces were immediately removed by software. By using microcontroller electronics came to simple and only basic components were required since all the regulation tasks were handled by microcontroller.

The article written by Jahan, (2003) was discussed the parameters that characterize water quality, measuring water quality parameters using analytical equipment and principle of coagulation flocculation process. Also he stated that turbidity, pH value, temperature, conductivity, dissolved oxygen and UV's absorption were the main parameters for coagulation flocculation process. Turbidity detection was used to measure the total solids content whereas UV's absorption detection could be employed to measure the total content of dissolved organic matter.

PIC Microcontroller Solutions including the microchip advantage, flexible programming options, PIC microcontroller migration strategy, PIC microcontroller product architectures (Baseline architecture, Mid-range architecture, High performance architecture), general purpose microcontroller features (Low power nanoWatt technology, high pin count high density memory, low pin count and space constrained, PIC microcontrollers with high voltage support and fan control capabilities), PIC microcontrollers with an integrated LCD module, PIC microcontrollers with integrated USB and PIC microcontrollers with Ethernet capabilities were demonstrated in http://www.microchip.com website, (2007).

Microcontroller Interfacing Techniques including advantages, disadvantages and examples of digital I/O control and monitoring, voltage based control and monitoring, parallel and serial bus, Asynchronous communication (1-wire, Rs232/RS485, Ethernet) and Synchronous communication (2-wire, 4-wire) were demonstrated in http://www.bipom.com website, (2007).

Project done by Arthur C. Clarke Institute for Modern Technologies, (2005) was revealed PIC microcontrollers are low cost, industry standard high performance and 8-bit with analogue to digital converters. They used PIC16F873 for their project of length counter.

Emunrud's (2002) research on Programmable Logic Controllers has addressed on the history of PLC development, the components that make up PLCs, need and current effort to standardize PLCs, advantages and disadvantages compared to other control systems. It concluded that the one major disadvantage to PLC was lack of standardization and this caused much confusion if the PLC used for an application was replaced by one from a different manufacturer, or if a PLC programmer was replaced by a person with a different understanding of PLC programming.

Chapter 3

Research Design and Methodology

3.1 Introduction

Main objective of this research is to develop models to automate Alum and Lime dosing for water treatment plant and to predict relationships between measuring parameters (turbidity and pH value) of water and amount of dosage of Alum and Lime.

3.2 Assumptions

Alum and Lime dosage is depends on water parameters of Turbidity, pH value, temperature, conductivity, dissolved Oxygen, UV's absorption, etc. However considering one water source conductivity, dissolved oxygen, temperature and UV's absorption remain same. Turbidity, number of particles in water is the main cause for optimum Alum dosage and pH value is the main cause for optimum Lime dosage.

Therefore Ambatale Water treatment plant which distributes water to Colombo area is selected for this research and followings are the basic information of it.

• Year Commissioned	:	1966 (Old Plant)
	:	1994 (New Plant)
• Water Source	:	Kelani River
• Water Intake	:	02 Pump Houses (Old & New)
	:	577,000 cum per day
• Sedimentation Tanks	:	05 Tanks capacity 61,300 cum each
	:	04 Tanks capacity 45,000 cum each

- Filters : 26 (18+8) Rapid Gravity Sand Filters

- Chemicals : Alum $Al_2(SO_4)_3 . 14H_2O$
  : Lime $Ca(OH)_2$ Chlorine gas Cl_2

- Water Storage : 03 Tanks (91,000, 4200, 6600 cum)

- Production per day : 470,000 cum (105 million gallons)

- Production Capacity (maximum) : 500,000 cum per day

Water Treatment Operation

The treatment plant gets its water supply from Kelani River. Water treatment involves physical chemical and biological processes that transform raw water into drinking water. Aeration, addition of chemicals, sedimentation, filtration and disinfection are the major steps. Aeration means air (oxygen) is introduced to water. By this means, the taste, colour and odour causing substances and gases are removed. Then chemicals, lime and alum are adding. When chemicals are added to water they react with soil and clay particles, microorganisms and other substances. This is called coagulation. These particles associate with similar particles to form big flocs. This process is called flocculation. The floes when it is heavy sink to the bottom. The result is clear water at the top. Then the sedimentation process is carried out. The flocs as stated above are formed in large sedimentation tanks. These clarification tanks are called pulsators, pre-treaters and centriflocs. Clear water is found at the surface of the tanks. This water is sent into the sand filters through a network of channels. The next step is filtration. Water is filtered through the rapid gravity sand filters. The suspended solids and some microorganisms are removed by the process. After that Alum is again added to do the pH correction. This is called as addition of post Lime. Last step of the water treatment process is disinfection. This is also called chlorination as it uses chlorine gas to disinfect water. Chlorine is a strong oxidizing agent and it destroys pathogens; that is disease causing organisms like bacteria remaining in the water.

Figure 3-1 shows layout diagram of Ambatale water treatment plant.

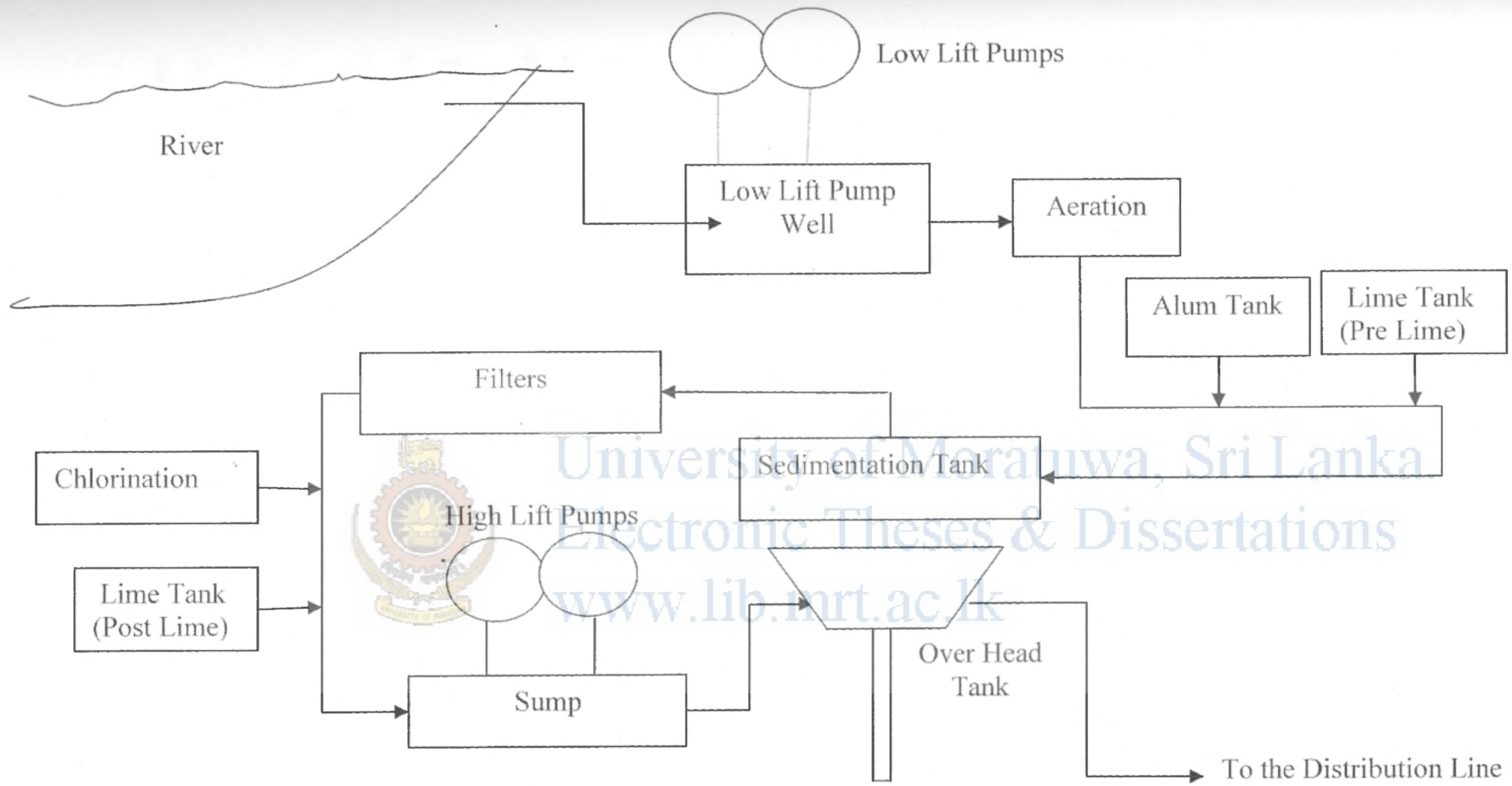


Fig 3-1 Layout Diagram of Ambatale Water Treatment Plant

3.3 Data Collection

This research is based on field data and experimental results using real data. One thousand number of jar test results for raw water were recorded (Appendix-A) to predict a relationship between measuring parameters (turbidity and pH value) of water and amount of dosage of Alum and Lime. Three hundred numbers of experiments are done to check the validity of results (Appendix-B).

3.4 Design of the System

Design of the Controller

This design is for controlling alum and lime dosing according to the turbidity and pH value of the incoming water. At the same time the system should indicate the value of turbidity and pH value in a display unit.

Features of the system are described below.

Since the dosing controller is designed using a microcontroller it allows for the flexibility of ease of operation.

The changing of dosage of Alum is occurred where the difference of turbidity value equal to ten (10) according to the initial value of turbidity. Then new value of turbidity is the initial value for next time.

The changing of dosage of Lime is occurred where the difference of pH values equal to point one (0.1) according to the initial value of pH value. Then new value of pH value is the initial value for next time.

Value of turbidity, value of pH, current dosing rates of alum and lime are indicated.

A master reset button can be used in case where the system locks-up due to some unpredictable event.

Selection of the Main Controller

To control the system, a microcontroller, a programmable logic controller or a PC using some form of I/O can be used.

Microcontrollers generally can be classified into 8-bit, 16-bit, and 32-bit family based on the size of their arithmetic and index register(s). It generally consists of ROM(Read Only Memory), RAM(Random Access Memory), Stack Pointers, Registers, Accumulator, Input/Output Ports, Timers, Analog to Digital Converter(ADC), Digital to Analog Converter(DAC), UART or SPI (for communication purposes). Some have special built in features that comes with Liquid Crystal Display Driver (LCD) that will enable them to drive LCD displays, EEPROM (Electrical Eraseable Programmable Read Only Memory) which is a non volatile memory that will enable it to store data permanently.

It can be implemented using high level language or assembly language. Clock speed determines how much processing can be accomplished in a given amount of time by the MCU. Some have a narrow clock speed range. Sometimes a specific clock frequency is chosen to generate another clock required in the system, e.g. for serial baud rates.

The processing technology of the microcontroller is N-channel metaloxide semiconductor (NMOS) or high-density complementary metal-oxide semiconductor (HCMOS). In HCMOS, signals drive from rail-to-rail, unlike earlier NMOS processors. Since these criteria can significantly affect noise issues in system design, HCMOS uses less power and thus generates less heat. The design geometries in HCMOS are smaller, which permit denser designs for a given size and thus allow higher bus speeds. The denser designs also allow lower cost, for more units can be processed on the same sized silicon wafer. For these reasons, most MCUs today are produced using HCMOS technology.

The advantages of microcontroller are that all MCUs have on-chip resources to achieve a higher level of integration and reliability at a lower cost. An on-chip resource is a block of circuitry built into the MCU which performs some useful function under control of the MCU. Built-in resources increase reliability because they do not require any external circuitry to be working for the resource to function. They are pre-tested by the manufacturer and conserve board space by integrating the circuitry into the MCU.

Some of the more popular on-chip resources are memory devices, timers, system clock/oscillator, and I/O. Memory devices include read/write memory (RAM), read-only memory (ROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), and electrically erasable memory (EEM). The term EEM actually refers to an engineering development version of an MCU where EEPROM is substituted for the ROM to reduce development time.

Timers include both real-time clocks and periodic interrupt timers. Other timer functions include timer compare and/or input capture lines.

I/O includes serial communication ports, parallel ports (I/O lines), analog-to digital (A/D) converters, digital-to-analog (D/A) converters, liquid crystal display drivers (LCD), and vacuum fluorescent display drivers (VFD).

Other built-in resources may include computer operating properly (COP) watchdog system which can be hardware or software based.

A microcontroller is a single integrated circuit. Integrating the memory and other peripherals on a single chip and testing them as a unit increases the cost of that chip, but often results in decreased net cost of the embedded system as a whole. Even if the cost of a CPU that has integrated peripherals is slightly more than the cost of a CPU + external peripherals, having fewer chips typically allows a smaller and cheaper circuit board, and reduces the labor required to assemble and test the circuit board.

Microcontrollers are useful to the extent that they communicate with other devices, such as sensors, motors, switches, keypads, displays, memory and even other micro-controllers. Many interface methods have been developed over the years to solve the complex problem of balancing circuit design criteria such as features, cost, size, weight, power consumption, reliability, availability, manufacturability.

Many microcontroller designs typically mix multiple interfacing methods. In a very simplistic form, a micro-controller system can be viewed as a system that reads from (monitors) inputs, performs processing and writes to (controls) outputs.

PLCs are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where changes to the system would not be expected during its operational life.

Very complex process control, such as used in the chemical industry, may require algorithms and performance beyond the capability. Very high-speed or precision controls may also require microcontroller solutions.

PLCs are not very good at handling large amount of data, or complex data. Microcontrollers are better for that. PLCs are also not very good with databases or displaying data.

Main Controller

The main controller is mainly established by using PIC16F876 microcontroller which is shown by Fig 3-2. This microcontroller has the following features that are best suited to conduct the task.

It process low cost, industry standard high performance and 8-bit with analogue to digital converters.

The support for a variety of range of input/output functions, and this microcontroller allow the user to determine whether to use a certain pin as input or output.

There are 192 bytes of RAM and has 22 input/output pins in additional several peripheral features such as timers, counters, etc.

There is also a serial port it capable of being programmed easily and interfaced with computer via standard RS232 port.

In this project MAX 7219 display driver IC can easily interfaced with microcontroller by using three wires (SDO, SDI and SCLK) and LOAD (CE) which is common today named as Serial Peripheral Interface (SPI).

The varieties of software tools are available for developing and debugging source code for the controller. The MPLAB software is used for developing the system because it is windows based an easy software development in 8-bit microcontroller.

The PIC16F876 chip is in electrical erasable packaged version (FLASH), and it is suitable for programming several times for testing our objective is implemented.

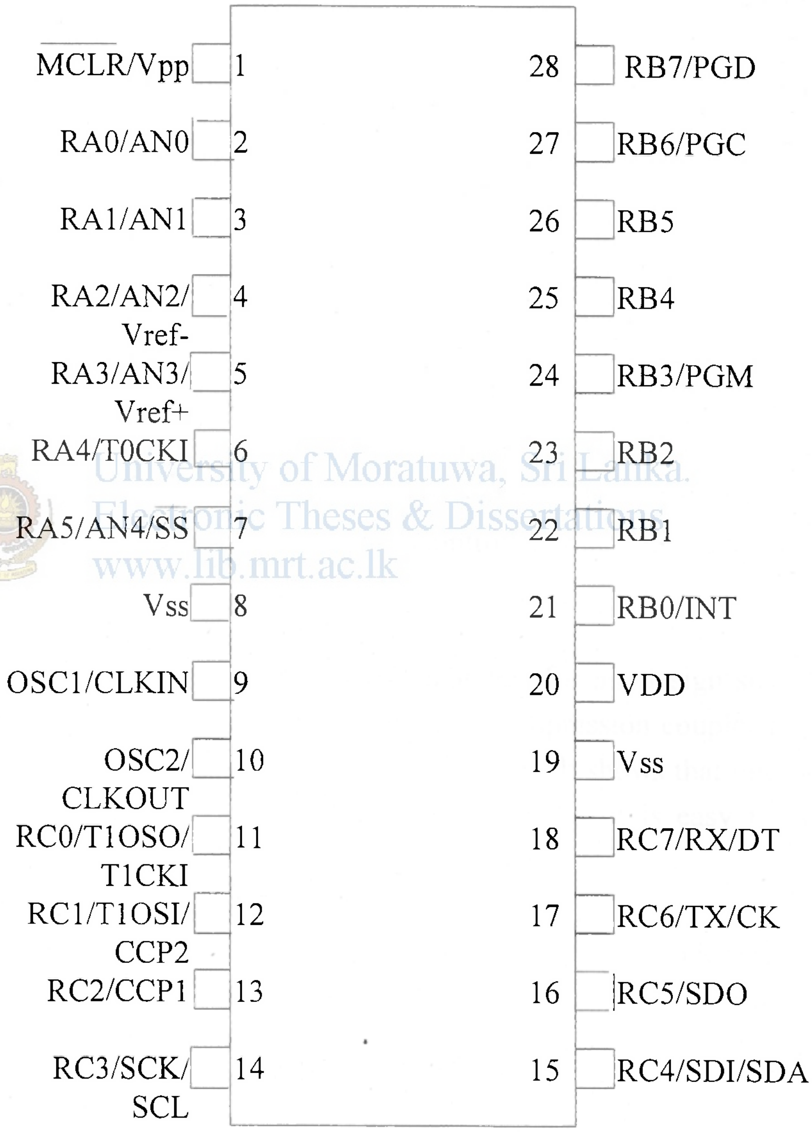


Fig 3-2: Pin Configuration of PIC16F876

Display Driver Unit

The display driver unit consists of 7-segment displays for visualizing the value of turbidity (or pH value) of the incoming water and the current dosage rate of Alum (or Lime). The MAX7219 display driver chip can derive multiplexed 7-segment displays, and convenient 3-wire serial interfacing with main controller. This IC is compact, common cathode display driver up to 8-digits. Included on chip is a BCD code-B decoder, multiplexer, scan circuitry of the display drivers, and on 8×8 static RAM that store each digit. The circuit of the display driver unit is shown in Fig 3-3.

Sensor Unit

The sensor is established in raw water just before adding Alum (or Lime) to measure the turbidity (or pH value). The turbidity sensor gives the interrupts to the microcontroller when the turbidity value is increased or decreased by 10 in ADC. The pH sensor gives the interrupts to the microcontroller when the turbidity value is increased or decreased by 0.1 in LDC.

Selected turbidity meter, WQ710 is perfectly matched for the design since it can be inserted into low pressure pipes by using standard compression coupler for turbidity monitoring and readings are giving every three seconds. It shows that output currents at the maximum turbidity values close to 20mA, so that it is easy to work with microcontroller.

Selected pH sensor, PH-BTA has an Ag-AgCl combination electrode with a range of 0 to 14 pH units. It is a high quality electrode for water quality monitoring. And also it is very compatible with microcontroller interfacing.

Stepper Motor

The stepper motor is to change the position of valve. Either increment or decrement of the value of turbidity by 10 valve position is changed according to the pre defined values in ADC. Either increment or decrement of the value of pH value by 0.1, valve position is changed according to the pre defined values in LDC.

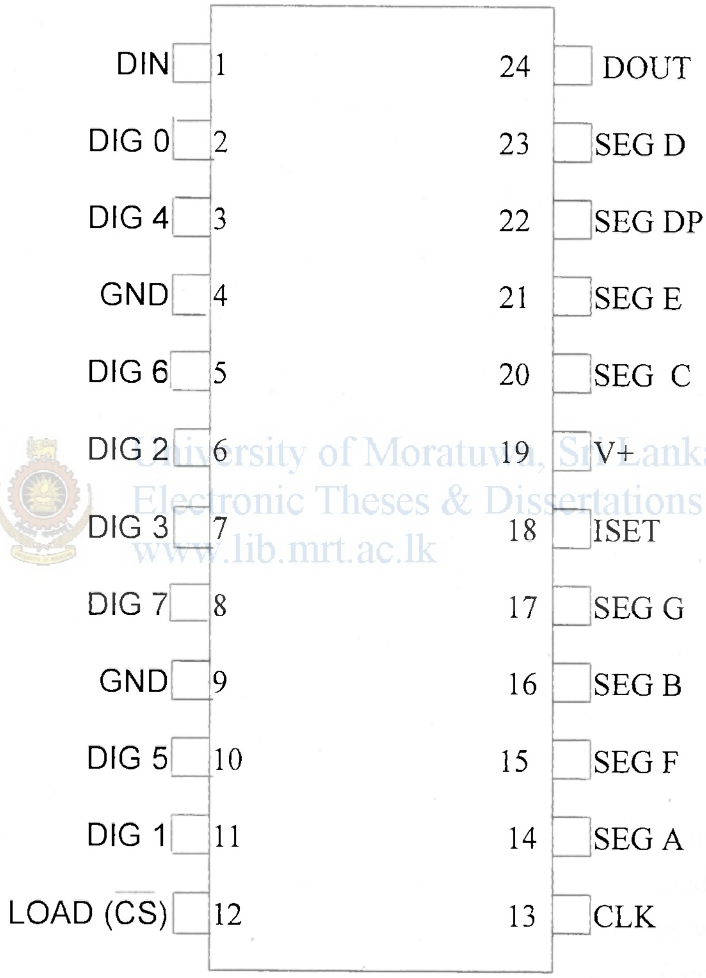


Fig 3-3: Pin Configuration of MAX7219

Stepper motors are commonly used in measurement and control applications. Following features are common to all stepper motors make them ideally suited for these types of applications.

Stepper motors are brushless. The commutator and brushes of conventional motors are some of the most failure – prone components and they create electrical arcs that are undesirable or dangerous in some environments.

Stepper motors will turn at a set speed regardless of load as long as the load does not exceed the torque rating for the motor.

Stepper motors move in quantified increment or steps. As long as the motor runs within its torque specification, the position of the shaft is known at all times without the need for a feedback mechanism.

Stepper motors are able to hold the shaft stationary. (Holding torque)

Stepper motors have an excellent response to start – up, stopping and reverse.

3.5 Methodology of the research

The study is based on primary data collection of jar test unit data. It is taken from Ambatale water treatment plant. Three no of jar tests are carried out per day. Data from May, 2006 to April, 2007 were recorded. Since it includes whole year both dry and rainy conditions are covered. Turbidity and pH value of incoming water, Alum requirement pre Lime requirement and post Lime requirement in ppm consist in the sample.

After analyzing the data, equations for optimum dosage of Alum and pre Lime with Turbidity and pH of incoming water are found respectively. Then three hundred real situations are taken and applied new results to them. There turbidity, pH value of raw water and turbidity, pH value at settled water at pulsators, pre-treaters and centriflocs, turbidity, pH value of filtered water and turbidity, pH value of final water are measured. Above procedure was done to check the validity of results.

Then the system is designed using PIC16F876 microcontroller as the controller. Source codes are constructed using Assembly codes. Value of turbidity is measured by a turbidity sensor. That value is taken to the microcontroller and it makes the decision of the Alum dosage and changes the valve position using stepper motor accordingly. Either increment or decrement of the value of turbidity by 10 makes the changing of valve position in ADC. Either increment or decrement of the value of pH value by 0.1 makes the changing of valve position in LDC Using MAX7219 IC value of current value of turbidity and current value of pH are displayed in ADC and LDC respectively.

Block diagram of the system is shown in Fig 3-4.

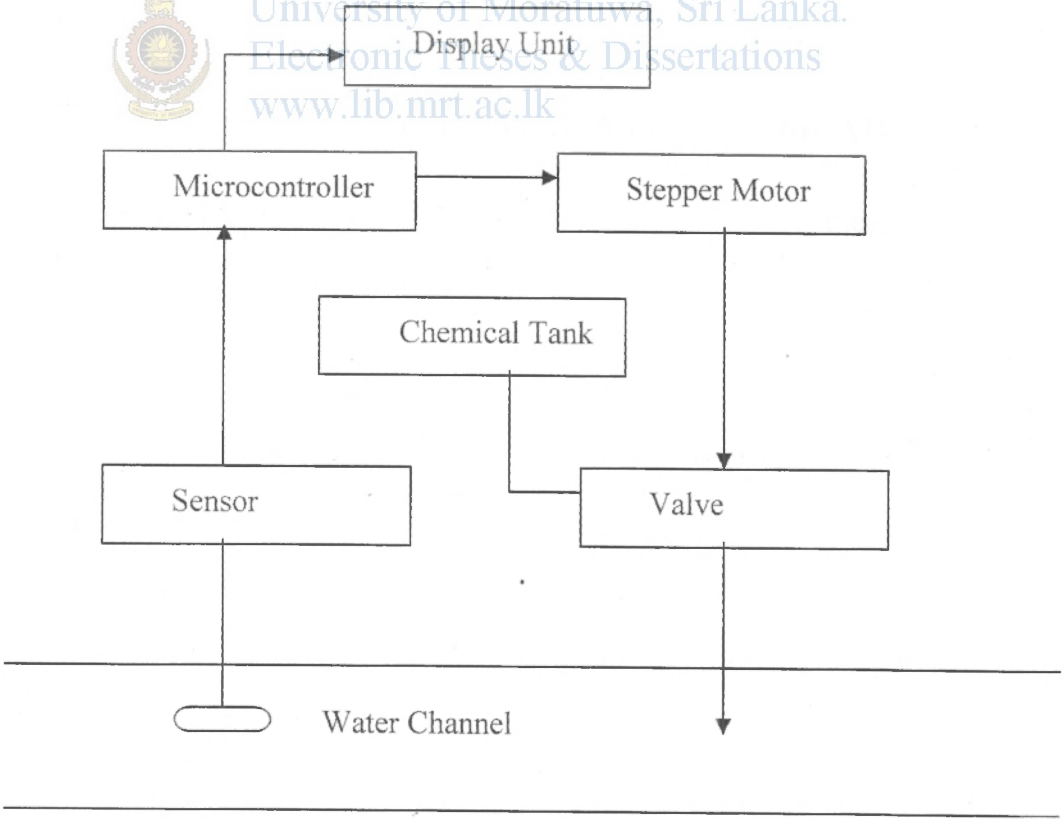


Fig 3-4: Block Diagram of the System

Chapter 4

Research Findings

4.1 Introduction

This chapter discussed the relationship of Alum dosage with turbidity for ADC, the relationship of Lime dosage with pH value for LDC, automotive systems of Alum dosing and Lime dosing and hardware design of the system and software design of the controller.

4.2 Constructed Relationships

Relationship of Alum dosage with turbidity for ADC

After analyzing of turbidity of raw water and Alum dosage which is measured by Jar test from May, 2006 to April, 2007 following graphs were obtained.

According to the jar test results value of turbidity and corresponding Alum requirement is plotted in x-y scatter chart in Microsoft Excel. Then a "best-fit" line was drawn through the data points.

First, best fit straight line was considered. It is shown in Fig 4-1. Linear regression technique is powerful tool to show that the data.points are fit into a straight line.

Given a set of data (x_i, y_i) with *n* data points, the slope, y-intercept and correlation coefficient, *r*, can be determined using the following:

$$m = \frac{n\sum(xy) - \sum x \sum y}{n\sum(x^2) - (\sum x)^2}$$

$$b = \frac{\sum y - m\sum x}{n}$$

$$r = \frac{n\sum(xy) - \sum x \sum y}{\sqrt{\left[n\sum(x^2) - (\sum x)^2\right]\left[n\sum(y^2) - (\sum y)^2\right]}}$$

(The limits of the summation, which are *i* to *n*, and the summation indices on *x* and *y* have been omitted.)

Correlation coefficient, *r* can take on values from 0 to 1, where 1 means there is a perfect match and means that all the points are on the line exactly.

(Most statistical texts show the correlation coefficient as "*r*", but Excel shows the coefficient as "*R*". Whether it is as *r* or *R*, the correlation coefficient gives us a measure of the reliability of the linear relationship between the *x* and *y* values).

According to the Fig 4-1,

- R-squared, r^2 = 0.7923
- Correlation Coefficient, r = 0.8901

Also the graph shows that best fit straight line is not suited to lower values and upper values of turbidity.

Therefore other best fit lines have to be considered. Fig 4-2 shows the Logarithmic line. Non linear regression technique is also same as linear regression technique. There also correlation coefficient, *r* can take on values from 0 to 1, where 1 means there is a perfect match and means that all the points are on the line exactly.

According to the Fig 4-2,

- R-squared, r^2 = 0.4944
- Correlation Coefficient, r = 0.7031

Also the graph shows that best fit logarithmic line is not suited to lower values and upper values of turbidity.

Therefore other best fit lines have to be considered. Fig 4-3 shows the second order polynomial line.

According to the Fig 4-3,

- R-squared, r^2 = 0.8573
- Correlation Coefficient, r = 0.9259

According to the results correlation coefficient, r value is close to 1 and that indicated excellent second order polynomial reliability.

However other best fit lines are also considered. Fig 4-4 shows the power line.

According to the Fig 4-4,

- R-squared, r^2 = 0.6504
- Correlation Coefficient, r = 0.8064

The graph shows that best fit logarithmic line is not suited to upper values of turbidity.

Fig 4-5 shows the exponential line.

According to the Fig 4-5,

- R-squared, r^2 = 0.8106
- Correlation Coefficient, r = 0.9003

Therefore best suited curve fit is polynomial. However high order polynomial reliability is also considered. Fig 4-6 shows the third order polynomial line.

According to the Fig 4-6,

- R-squared, r^2 = 0.8575
- Correlation Coefficient, r = 0.9260

Fig 4-7 shows the fourth order polynomial line.

According to the Fig 4-7,

- R-squared, r^2 = 0.8577
- Correlation Coefficient, r = 0.9261

Fig 4-8 shows the fifth order polynomial line.

According to the Fig 4-8,

- R-squared, r^2 = 0.861
- Correlation Coefficient, r = 0.9279

Fig 4-9 shows the sixth order polynomial line.

According to the Fig 4-9,

- R-squared, r^2 = 0.8619
- Correlation Coefficient, r = 0.9283

Table 4-1: Details of R-Squared Value with Different Lines

Best fit	R-squared, r^2	Correlation Coefficient, r	1-r
1. Straight line	0.7923	0.8901	0.1099
2. Logarithmic line	0.4944	0.7031	0.2969
3. Second Order Polynomial	0.8573	0.9259	0.0741
4. Third Order Polynomial	0.8575	0.9260	0.0740
5. Fourth Order Polynomial	0.8577	0.9261	0.0739
6. Fifth Order Polynomial	0.861	0.9279	0.0721
7. Sixth Order Polynomial	0.8619	0.9283	0.0717

According to the table Correlation Coefficient, r is considerably near to 1 in polynomial line. Therefore this data is reliable for polynomial. And also it reveals that higher the order of the polynomial, better the curve fit. But Correlation Coefficient, r is changing considerably small. Therefore second order polynomial is reliable for data points.

Fig 4-1 : Linear Relationship of Turbidity and Alum Dosage

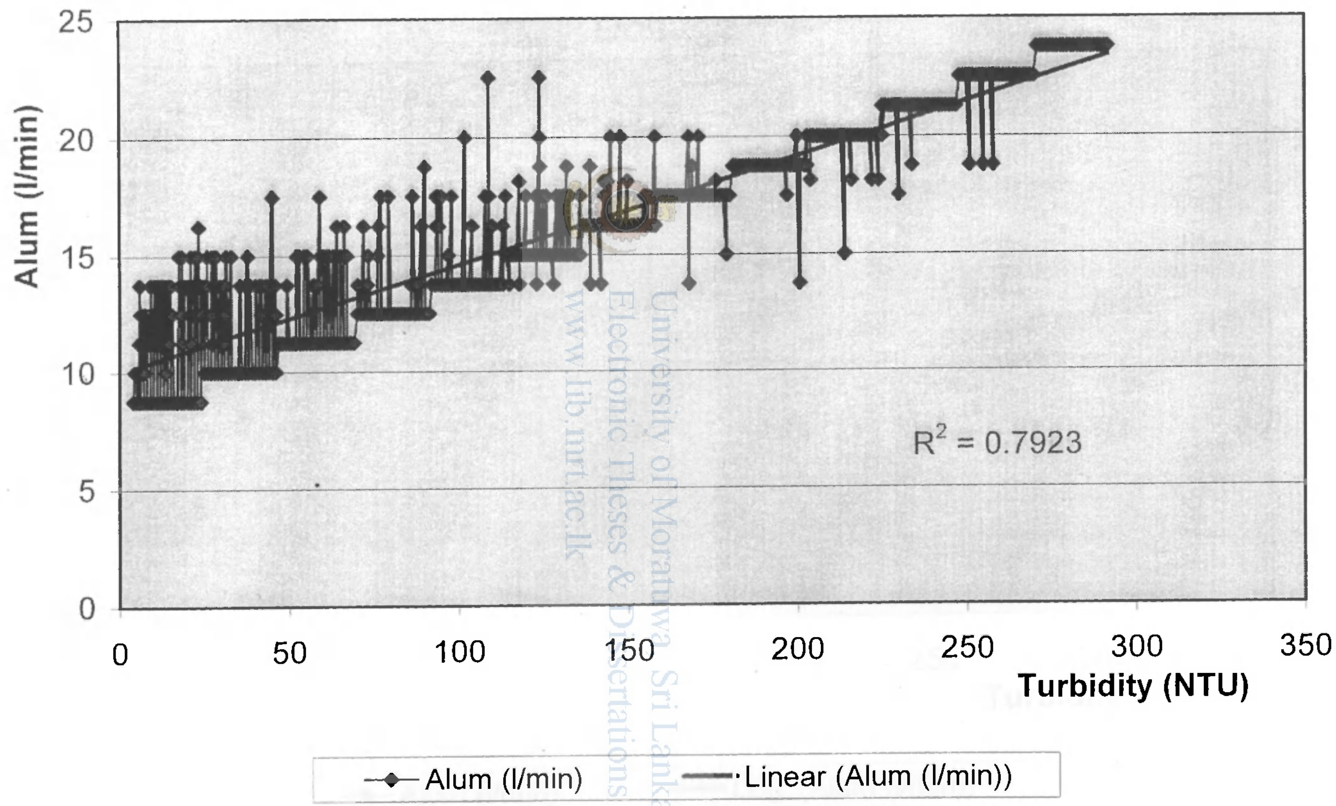


Fig 4-2 : Logrithmic Relationship of Turbidity and Alum Dosage

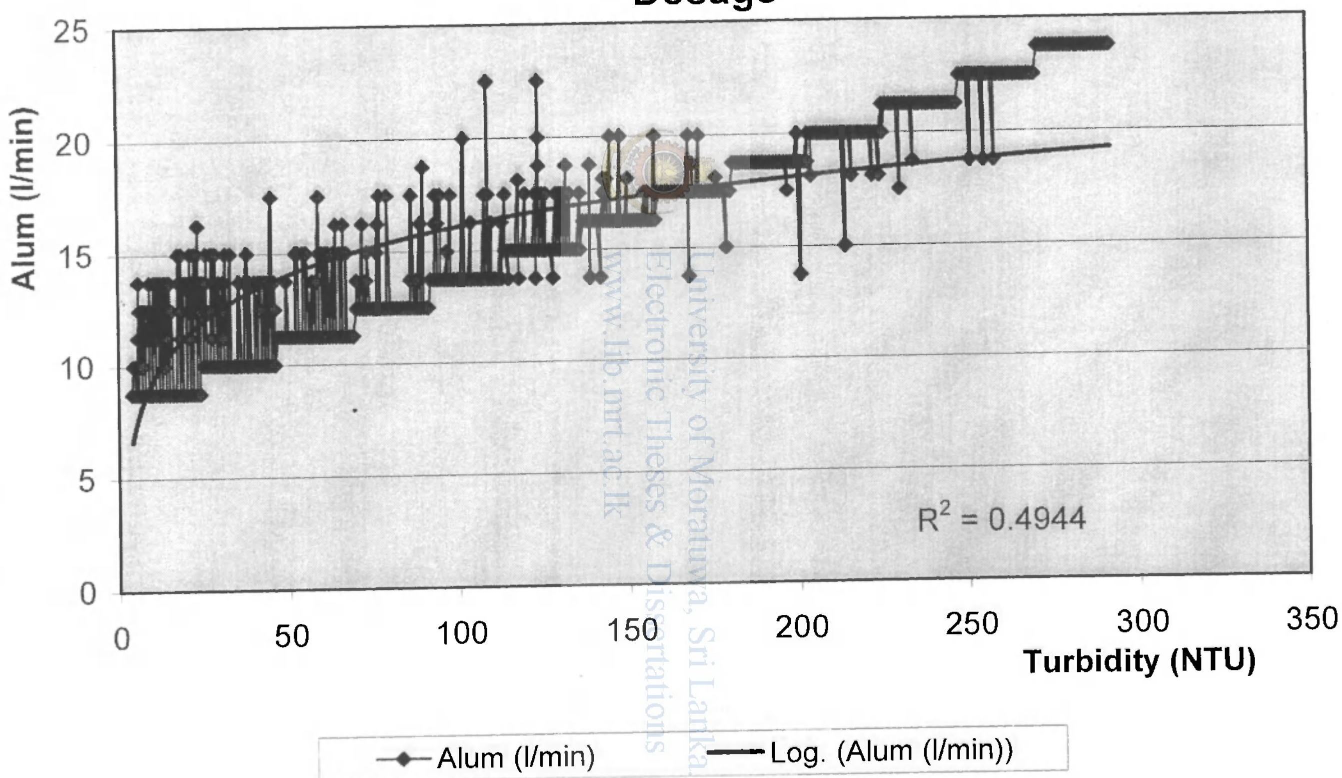


Fig 4-3 : Second Order Polynomial Relationship of Turbidity and Alum Dosage

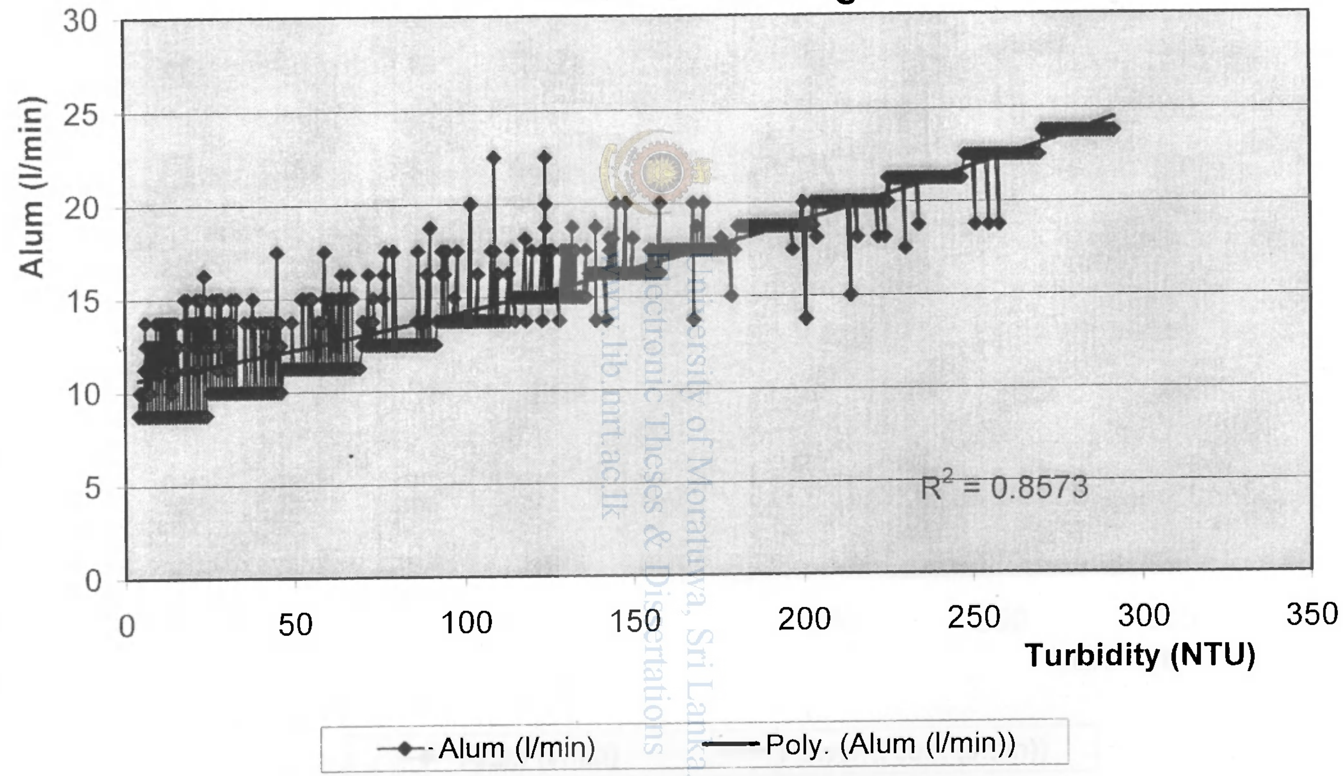


Fig 4-4 : Power Relationship of Turbidity and Alum Dosage

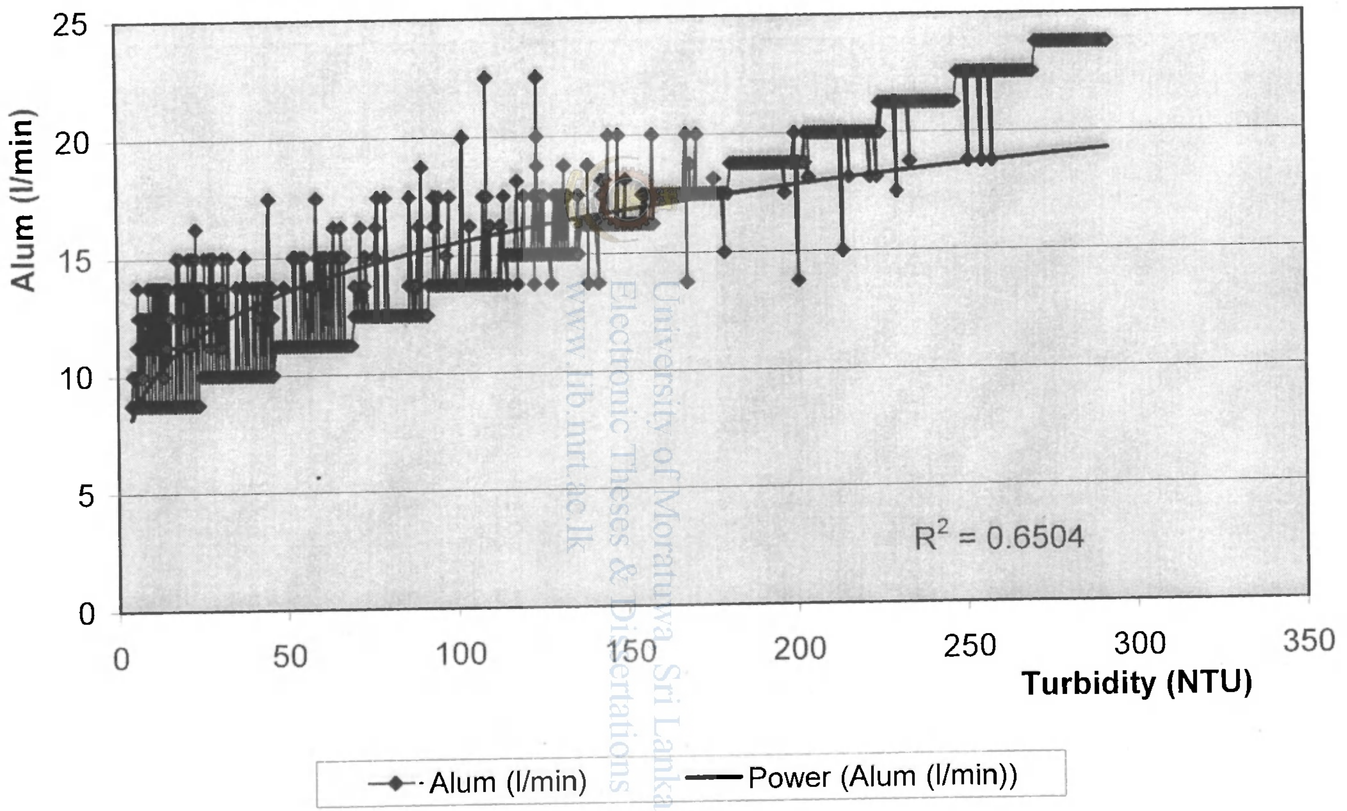


Fig 4-5 : Exponential Relationship of Turbidity and Alum Dosage

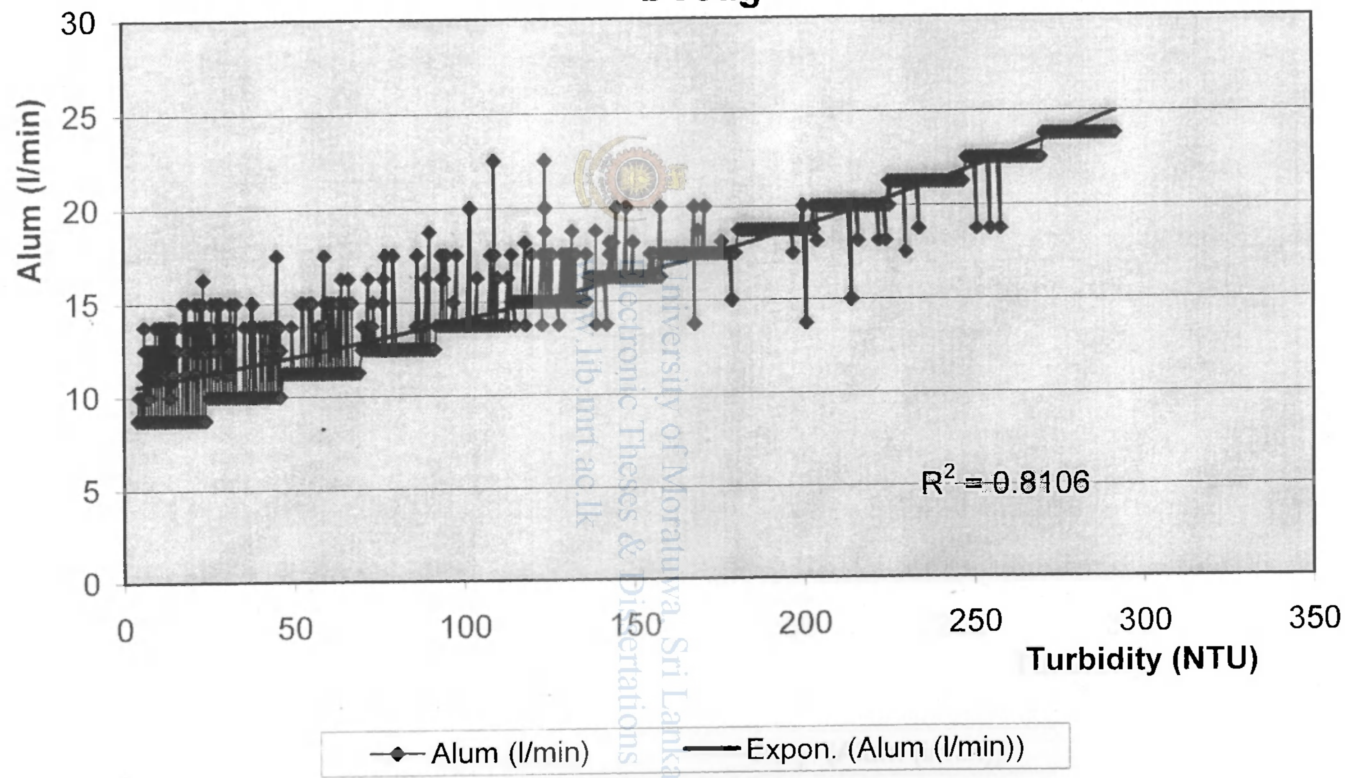


Fig 4-6 : Thired Order Polynomial Relationship of Turbidity and Alum Dosage

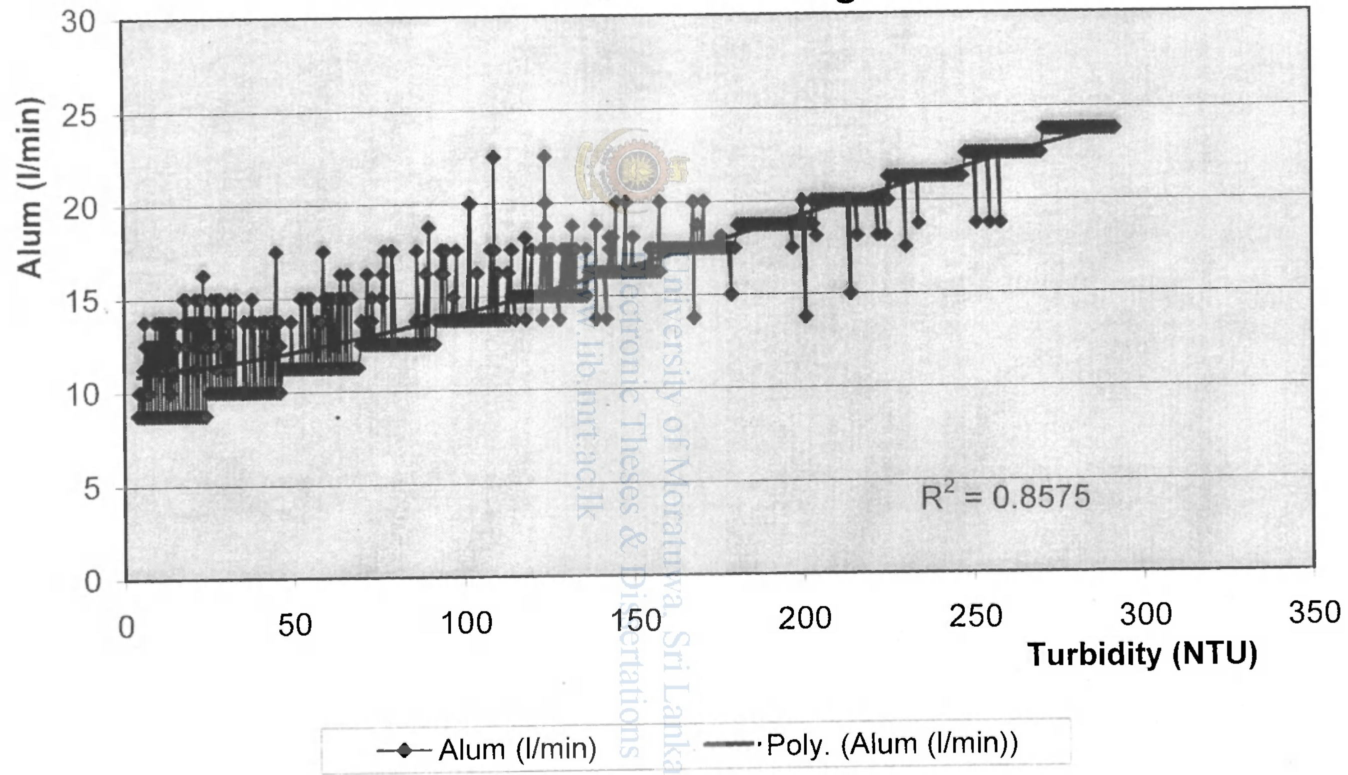
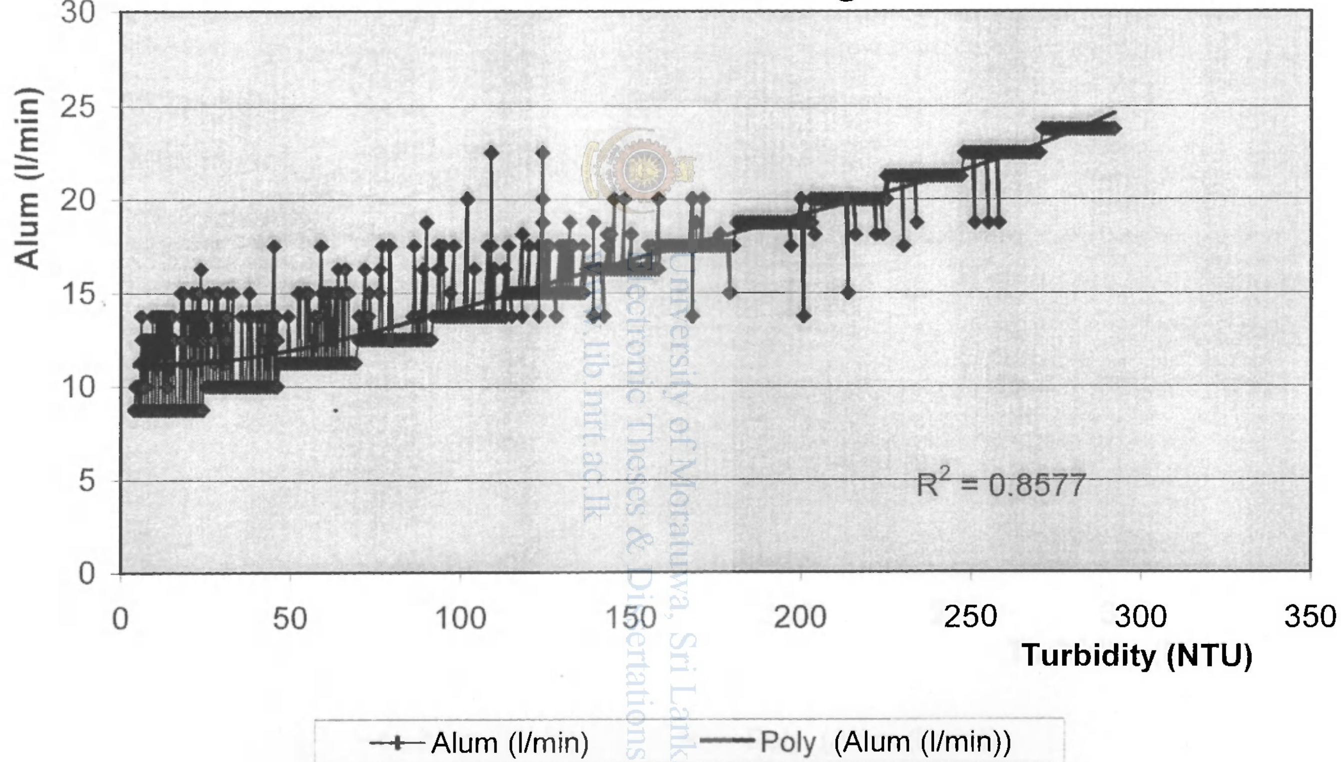


Fig 4-7 : Fourth Order Polynomial Relationship of Turbidity and Alum Dosage



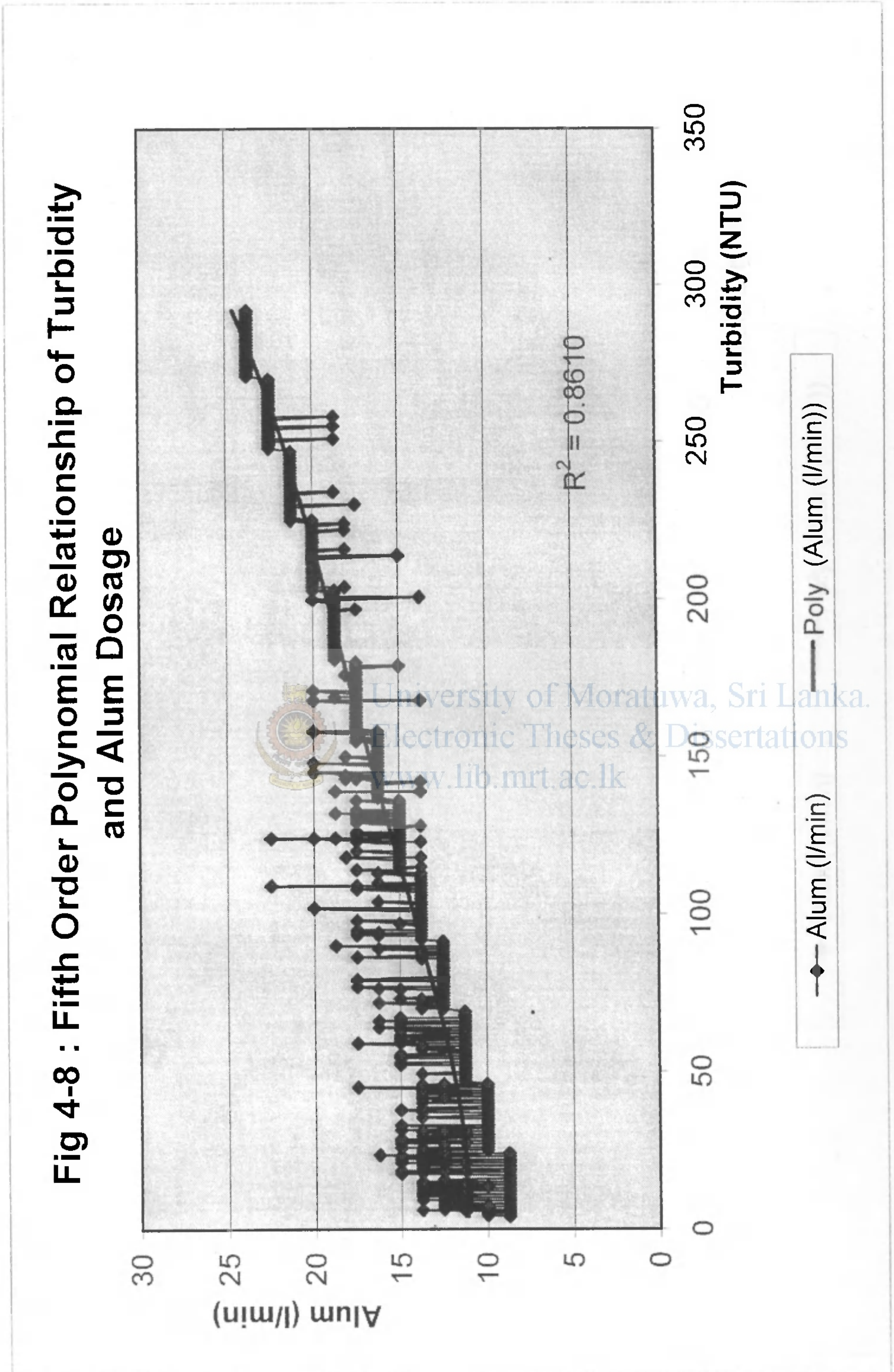
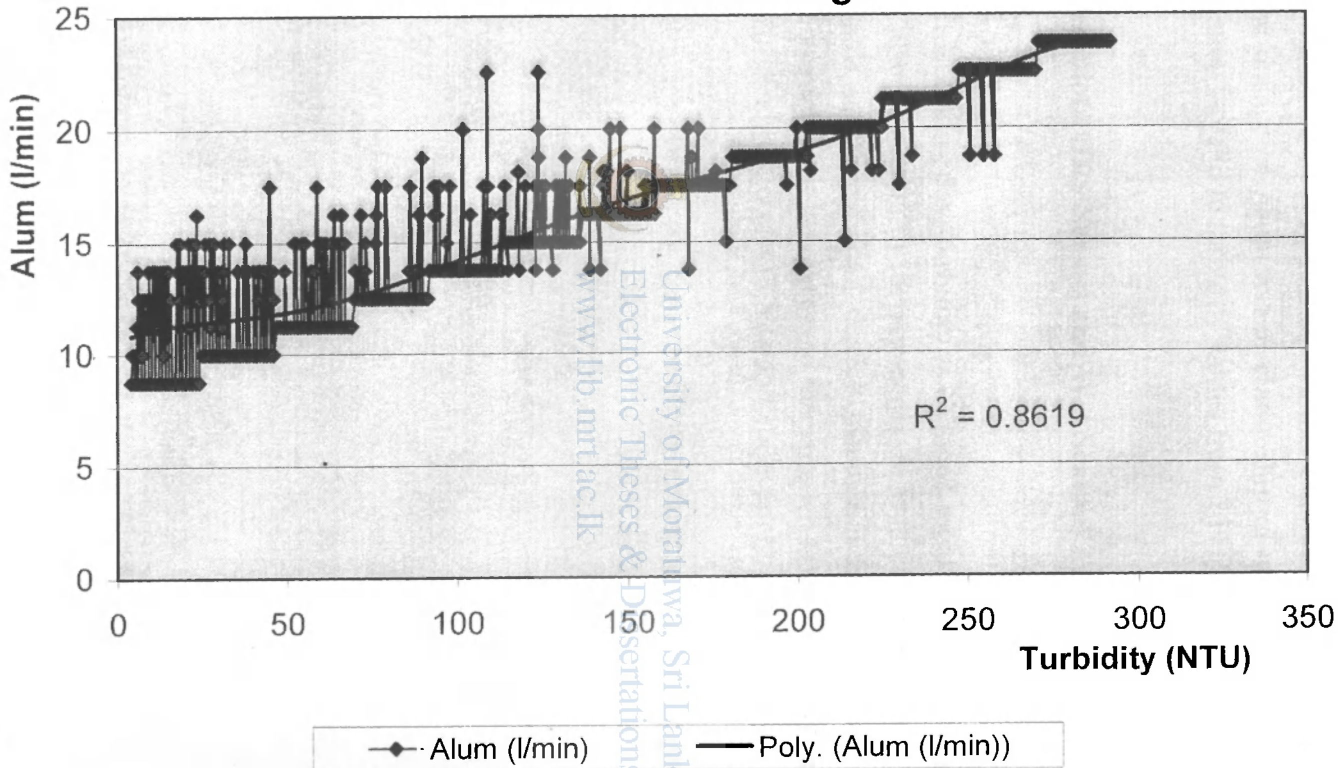


Fig 4-8 : Fifth Order Polynomial Relationship of Turbidity and Alum Dosage

Fig 4-9 : Sixth Order Polynomial Relationship of Turbidity and Alum Dosage



Relationship

$$\left.\begin{array}{l}\textbf{OPTIMUM ALUM}\\ \textbf{DOSSAGE (l/min)}\end{array}\right\} = 10 + 0.05\,(\text{TURBIDITY}) + 6 \times 10^{-5}\,(\text{TURBIDITY})^2$$

Turbidity is measured in NTUs. It shows that relationship of turbidity value of raw water and the dosage of Alum has a relationship of second order polynomial. And also this equation is valid to turbidity values from 2 NTU to 300 NTU.

Seasonal Variations (Dry Season and Wet Season)

In Sri Lanka only two seasonal changes are occurred, dry season and wet season. However if it is a rainy day, turbidity is changed rapidly both in wet season and dry season. And also according to the Appendix-A, it is observe that for same turbidity values has same optimum Alum dosage whether it belongs to dry season or wet season. For an example, it is considered the samples from 825 to 860 in Appendix-A. Then the season is checked and following details are obtained.

Therefore optimum dosage for same turbidity values may not changed according to the season.

Table 4-2: Details of Seasonal Variations

Sample No	Turbidity (NTU)	Alum (ppm)	Alum (l/min)	Dry Season	Wet Season
825	204.0	16	20	√	
826	204.0	16	20		√
827	205.0	16	20	√	
828	205.0	16	20		√
829	206.0	16	20		√
830	206.0	16	20		√
831	207.0	16	20		√
832	207.0	16	20		√
833	208.0	16	20	√	
834	208.0	16	20		√
835	209.0	16	20		√
836	209.0	16	20	√	
837	209.0	16	20		√
838	210.0	16	20		√
839	210.0	16	20		√
840	211.0	16	20	√	
841	211.0	16	20	√	
842	212.0	16	20		√
843	212.0	16	20		√
844	213.0	16	20		√
845	213.0	16	20		√
846	214.0	12	15	√	
847	214.0	16	20		√
848	214.0	16	20		√
849	215.0	16	20		√
850	215.0	16	20	√	
851	216.0	14.5	18.13		√
852	216.0	16	20		√
853	216.0	16	20		√
854	217.0	16	20		√
855	217.0	16	20		√
856	218.0	16	20	√	
857	218.0	16	20		√
858	219.0	16	20		√
859	219.0	16	20		√
860	220.0	16	20		√

Relationship of Lime dosage with pH value for LDC

After analyzing of turbidity of raw water and Alum dosage which is measured by Jar test from May, 2006 to April, 2007, Table 4-3 is obtained.

Table 4-3 Details of Experimental Lime Dosage for Different pH Values

pH Value	No of Samples	Lime Dosage (l/min)							
		17.5	15	12.5	10	7.5	5	2.5	0
5.8	54	**53**		1					
5.9	54	1	**52**	1					
6.0	54	1	**53**						
6.1	56			**56**					
6.2	70		1	**57**	12				
6.3	77		4	8	**65**				
6.4	116	3	2	23	**85**	3			
6.5	147		1	16	48	**78**			4
6.6	101			3	29	**66**	1		2
6.7	79					3	**73**		3
6.8	65					1	**59**	3	2
6.9	68					1	7	**59**	1
7.0	54				1				53
7.1	2								2
7.2	1								1
7.3	2								2

According to the Table 4-3, it shows that for all individual pH value has particular optimum Lime dosage which has occurred frequently. As an example, when pH value is equal to 6.3, optimum Lime dosage is 10 l/min in 65 times out of 77 samples. Therefore pH value of raw water and the optimum dosage of Lime have stepwise relationship.

Table 4-4 Requirement of Alum dosage for different pH values

pH value	Lime Dosage (l/min)
5.8	17.5
5.9	15.0
6.0	15.0
6.1	12.5
6.2	12.5
6.3	10.0
6.4	10.0
6.5	7.5
6.6	7.5
6.7	5.0
6.8	5.0
6.9	2.5
7.0	0.0
7.1	0.0
7.2	0.0
7.3	0.0

Validity of the Equations

After obtaining optimum values for Alum and Lime dosage, they were applied to three hundred real situations. Then quality of final water was measured. According to the WHO (World Health Organization) Guide Lines, recommended value of turbidity is smaller than 5 and recommended pH value is smaller than 8. Those conditions are satisfied. Therefore relationships for optimum dosage of Alum and Lime are accurate.

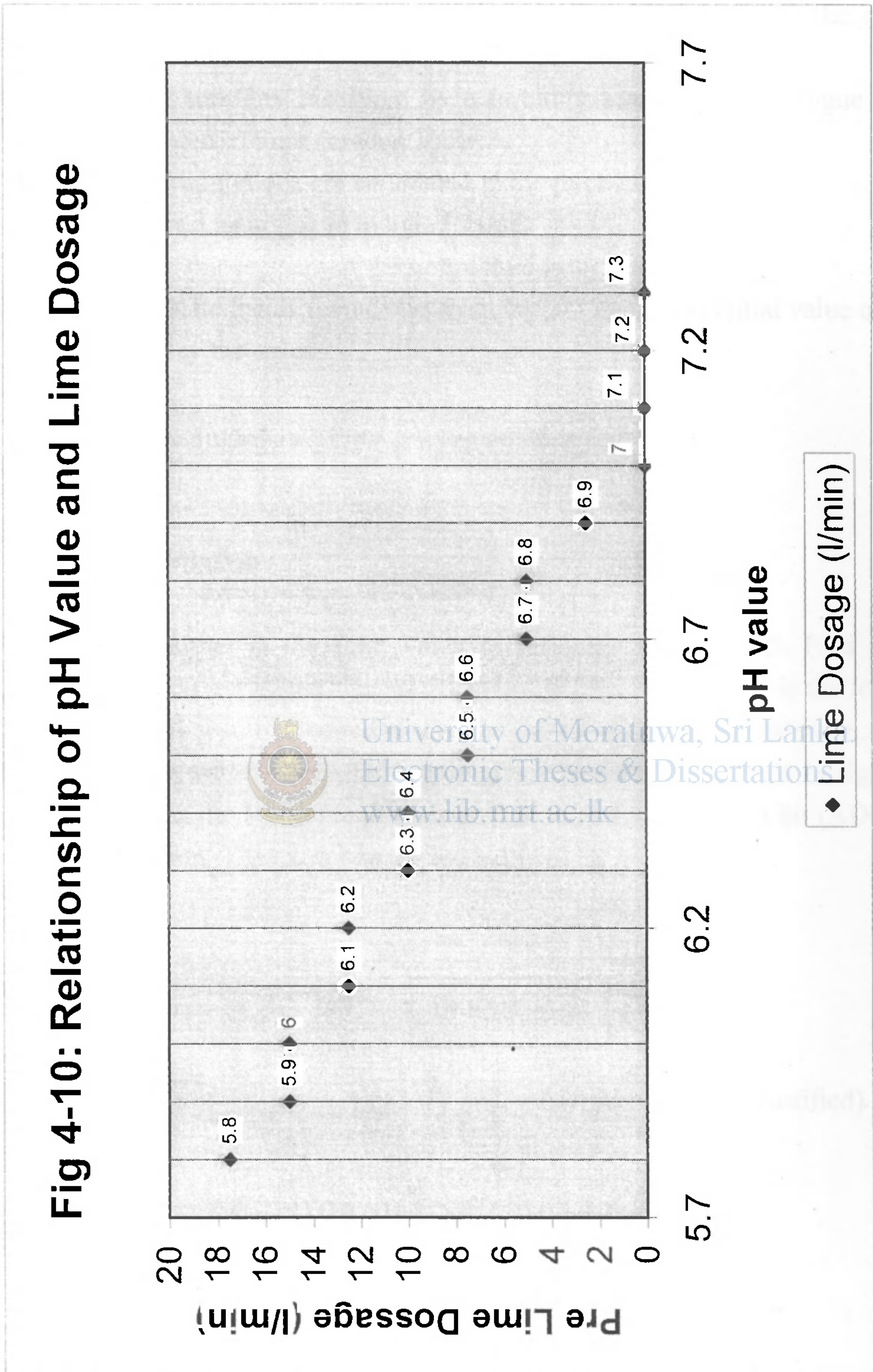


Fig 4-10: Relationship of pH Value and Lime Dosage

4.3 Development of the system

The Fig 4-11, system diagram illustrates the basic structure used by the system.

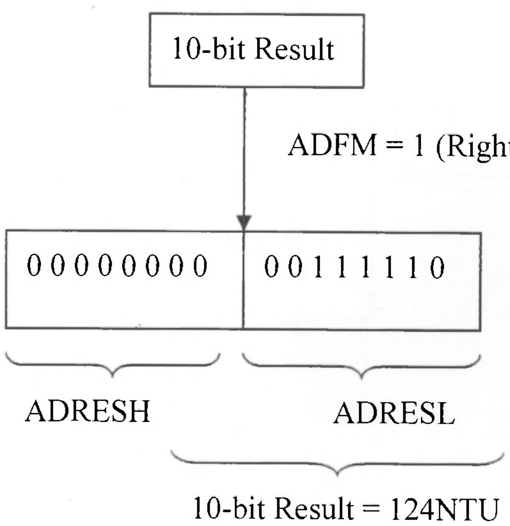
The value of turbidity measured by a turbidity sensor is an analogue value that is given as an input to the microcontroller.
Following computations are conducted in the microcontroller.

- Convert analogue to a digital value.
- Make the decision of the optimum dosage value.
- Calculate the difference between current value and initial value of turbidity.
- Display the value

The above mentioned functions are explained with an example.

Sample Calculation

Let's assume that at the start, value of turbidity is 124 NTU. First that value is converted to digital value. The ADRESH:ADRESL register pair is the location where the 10-bit A/D result is loaded at the completion of the A/D conversion. This register pair is 16-bits wide. The A/D module gives the flexibility to left or right justify the 10-bit result in the 16-bit result register. The A/D Format Select bit (ADFM) controls this justification. The extra bits are loaded with '0' s.



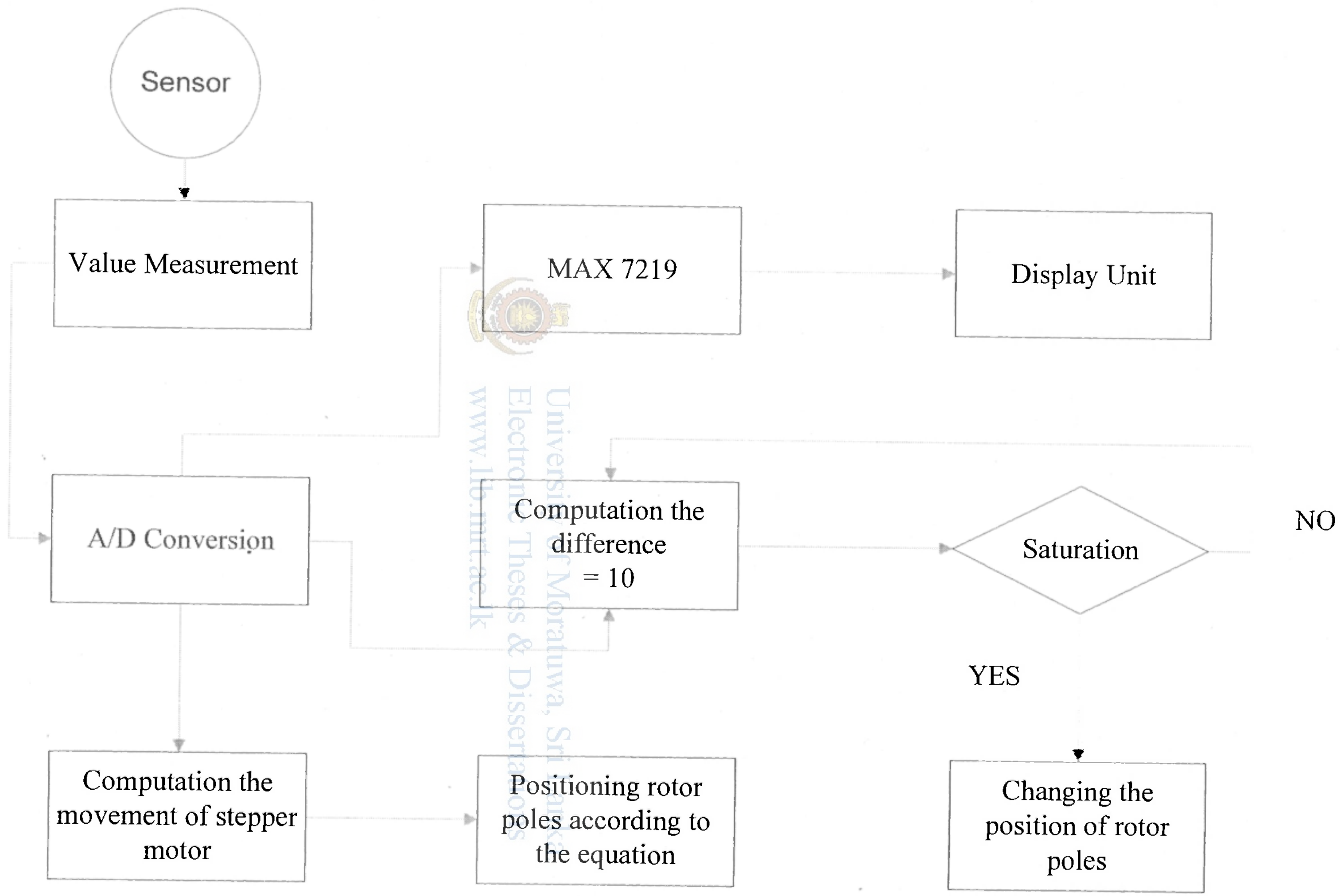


Fig 4-11 System Diagram

The data base is developed to find the optimum Alum dosage (Refer Appendix-D). It is based on the equation obtained between the value of turbidity and the optimum alum dosage (Optimum Alum Dosage = $10 + 0.05 \times (\text{Turbidity}) + 6 \times 10^{-5} \times (\text{Turbidity})^2$).

According to the field data turbidity varies from 4 NTU to 292 NTU. Therefore half step mode permanent magnet stepper motor with 1.8° step angle is used. In Appendix-D, angle movement of stepper motor for different turbidity values is also shown. Then the criterion is defined to select the angle movement of stepper motor with digital value of turbidity in the source code (Appendix-C).

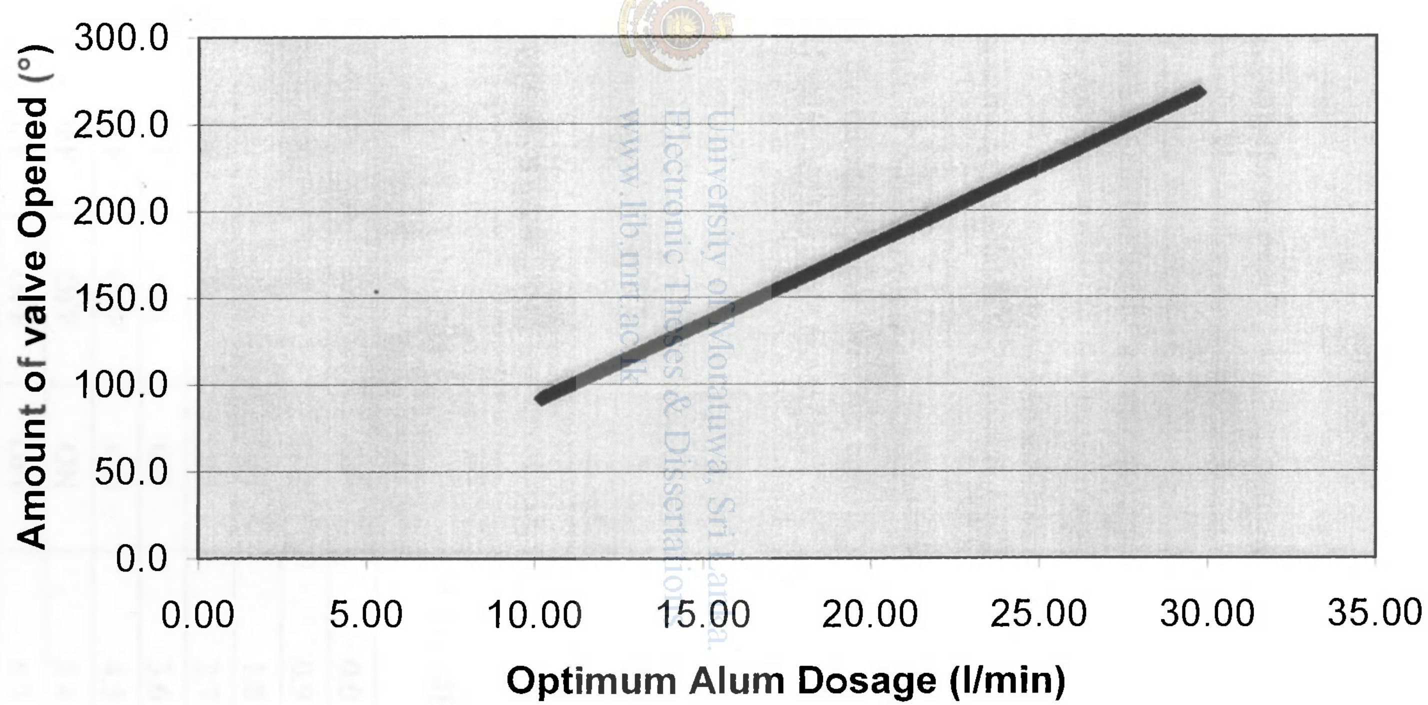
As per the example, angle movement of the stepper motor is 154.1°. Since the optimum Alum dosage is proportional to the angle movement of stepper motor, optimum Alum dosage is also proportional to amount of valve opened. Figure 4-12 shows the relationship of amount of valve opened and optimum Alum dosage.

Then also a loop is defined to giving interrupts when turbidity value is changed by 10.

Initial value	-	124NTU	-	'0000111110'
Saturation value	-	134NTU	-	'0010000110'

Then the flag is on and change the angle accordingly. Movement of the angle for 134NTU is 160°.

Fig: 4-12 Relationship of Amount of Valve Opened and Optimum Alum Dosage



Design of the hardware

The Fig 4-12, shows the Schematic Diagram of the Hardware used by the system.

Following major components are indicated in the diagram.

- A/D converters
  The Analog to digital converter module has five inputs for the 28 pin devices and eight for the other devices. The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The A/D conversion of the analog input signal results in a corresponding 10 bit digital number. The A/D module has high and low voltage reference input that is software selectable to combination of RA2 and RA3.

- Selection and calculation of motor position
  Selection is done by the microcontroller from the criteria written with referring Appendix-D, turbidity value and the angle movement.

- Stepper motor controlling

  Table 4-5 shows the sequence.

Table 4-5: The sequence of switching the windings of ADC

STEP	STATOR WINDING				MOVEMENT (°)
	1	2	3	4	
0	ON	ON	OFF	OFF	0.0
0.5	OFF	ON	OFF	OFF	0.9
1	OFF	ON	ON	OFF	1.8
1.5	OFF	OFF	ON	OFF	2.7
2	OFF	OFF	ON	ON	3.6
2.5	OFF	OFF	OFF	ON	4.5
3	ON	OFF	OFF	ON	5.4
3.5	ON	OFF	OFF	OFF	6.3
4	ON	ON	OFF	OFF	7.2

Either increment or decrement of the value of pH value by 0.1 makes the changing of valve position in LDC. Alum is changed from 5.5 to 7.5. Full step mode permanent magnet stepper motor with 15° step angle is used. Table 4-6 shows the sequence.

Table 4-6: The sequence of switching the windings of LDC

STEP	STATOR WINDING				MOVEMENT (°)
	1	2	3	4	
0	ON	ON	OFF	OFF	0
1	OFF	ON	ON	OFF	15
2	OFF	OFF	ON	ON	30
3	ON	OFF	OFF	ON	45
4	ON	ON	OFF	OFF	60

- Display unit using MAX7219

The MAX7219 drives common-cathode LED displays from one to eight seven-segment digits in length. It can also be used to drive up to 64 discrete LEDs configured as eight common-cathode clusters of eight LEDs each.

When the MAX7219 is used with seven-segment displays, it can be configured to automatically convert binary-coded decimal (BCD) values into appropriate patterns of segments.

The MAX7219 interfaces with controllers through three pins: data in, clock, and load. It connects to the LED displays in a straightforward way; pins SEG A through SEG G and SEG DP connect to segments A through G and the decimal point of all of the common-cathode displays. Pins DIGIT 0 through DIGIT 7 connect to the individual cathodes of each of the displays.

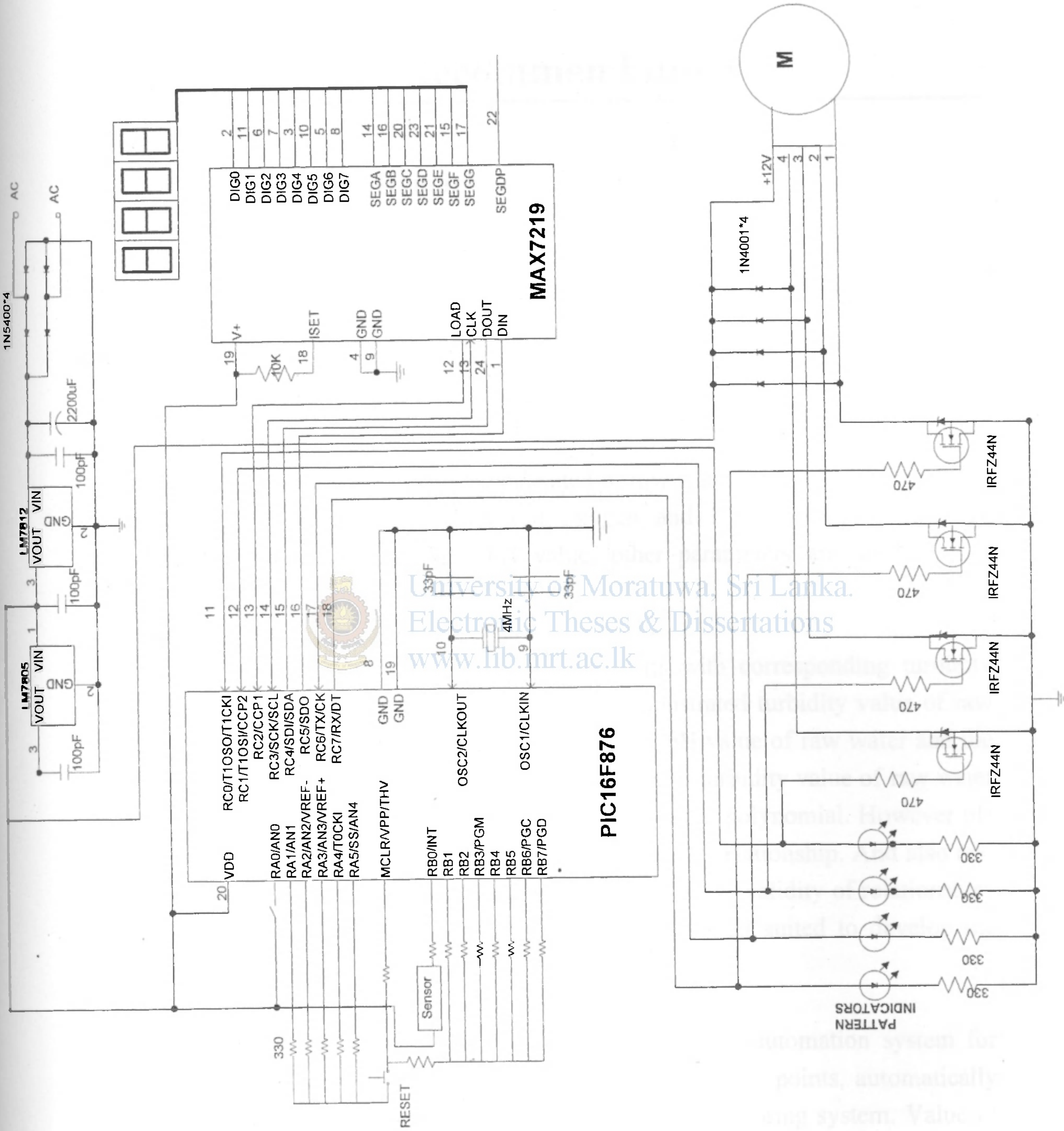


Fig 4-12: Schematic Diagram of the Hardware

Chapter 5

Conclusions and Recommendations

5.1 Conclusions, Remarks and Discussion

To conclude, this research adhered to the initial objectives, which were stated. The major activity of this research was to propose an alternative to the jar test allowing for an on line determination of optimal coagulant dosage from raw water characteristics and design a system for feeding Alum and Lime automatically with a monitoring display.

Coagulant dosing rate is non-linearly correlated to raw water parameters of turbidity, conductivity, pH, temperature, dissolved oxygen and UV's absorption. It was assumed that except turbidity and pH value, other parameters are almost same throughout year.

After analyzing thousand number of jar test results with corresponding turbidity values and pH value of incoming water, it was demonstrated turbidity value of raw water and the dosage of Alum has a relationship and pH value of raw water and the dosage of Lime has another relationship. Relationship of turbidity value of raw water and the dosage of Alum has a relationship of second order polynomial. However pH value of raw water and the dosage of Lime have stepwise relationship. And also real three hundred situations were taken and applied to check the validity of relationships and it proved that relationship which has obtained are well suited to develop the automation system.

The major component of the research is designing a fully automation system for measuring the turbidity and pH value, deciding the operating points, automatically changing the dosage accordingly and turbidity and pH monitoring system. Value of turbidity was measured by a turbidity sensor. That value was taken to the microcontroller and it decided the Alum dosage and changes the valve position using stepper motor accordingly. Either increment or decrement of the value of turbidity by

10 makes the changing of valve position in ADC. Either increment or decrement of the value of pH value by 0.1 makes the changing of valve position in LDC.
Using MAX7219 IC value of current value of turbidity and current value of pH are displayed in ADC and LDC respectively.

System consists three major parts. They are sensors (turbidity sensor for ADC and pH sensor for LDC), controller and stepper motor. Selected turbidity meter, WQ710 was perfectly matched for the design since it can be inserted into low pressure pipes by using standard compression coupler for turbidity monitoring and readings are giving every three seconds. It showed that output currents at the maximum turbidity values close to 20mA, so that it is easy to work with microcontroller.

PIC16F876 microcontroller is selected as the controller; it made the task easier. Since PIC16F876 has 8-bit with analogue to digital converters it handled analogue output of turbidity sensor and pH sensor. In this project MAX 7219 display driver IC could be easily interfaced with microcontroller by using three wires (SDO, SDI and SCLK) and LOAD (CE) which is common today named as Serial Peripheral Interface (SPI). The PIC16F876 chip is in electrical erasable packaged version (FLASH), and it helped for programming several times for testing our objective is implemented. PIC16F876 was simple for motor controlling specially stepper motor controlling.

The varieties of software tools are available for developing and debugging source code for the controller. The MPLAB software is used for developing the system which is windows based an easy software development in 8-bit microcontroller and it made developing and debugging the source code easy and simple.

5.1 Recommendations for Future Research

The recommendations given in this chapter is mainly based on the research findings.

All this research shows that any complex situation can be handled by doing reasonable assumptions and using simple selections. Tropical countries like Sri Lanka can use this simplification method for different lakes and rivers. After analyzing a water source, relationships for Alum and Lime dosing with turbidity and pH value can be found. For Kelani River relationship of turbidity value of raw water and the dosage of Alum has a relationship of second order polynomial and pH value of raw water and the dosage of Lime have stepwise relationship.

Since such relationship is found controlling part became easier and low cost. The main controller, which is PIC16F876, handled A/D converting and stepper motor controlling perfectly. And also MAX 7219 display driver IC is easily interfaced with microcontroller. The MPLAB software is used for developing the system has developed and debugged the source code easily.

Considering the practical situation constructing such equipment is low cost. And also it can decrease operational cost, chemical cost, laboratory tests and unnecessary man-hours.

References

Baba, K., Enbutsu, I., Matuzaki, H. & Nogita, S.,1990. *Intelligent support system for water and sewage treatment plants which included past history learning function – coagulation injection guidance system using neural net algorithm.*

Baxter, C. W., 1998. *Full scale artificial neural network modeling of enhanced coagulation.* M.Sc. Thesis, University of Alberta.

Baxter, C.W., Stanley, S.J., Zhang, Q. & Smith, D.W., 2002. Developing artificial neural network models of water treatment processes: A guide for utilities, *Engineering Science*, p.201-211.

Bernazeau, F., Pierrone, P. & Duguet, J.P., 1992. Interest in using a streamline current detector for automatic coagulant dose control. *Water Supply*, 10 (4), 87-96.

BiPOM Electronics, Inc., 2005. *Microcontroller interface techniques*, [Online].Available at: http://www.bipom.com [accessed June 2007].

Chazal, D., 2006. *Controlling oxygen sensors with an automotive microcontroller*, Masters Degree Project. Royal Institute of Technology.

Dentel, K.S., 1995. Use of streaming current detector in coagulation monitoring and control, *Water Sensors and Research and Technologies –Aqua*, 44, p.70-79.

Emunrud, A., 2002. *Programmable logic controllers.*

Evans, J., Enoch, C., Johnson, M. & Williams, P., 1998. Intelligent based auto coagulation control applied to a water treatment works. *In international conference on control.*

Gagnon, C., Grandjean, B.P.A. & Thibault J., 1997. *Modeling of coagulant dosage in a water treatment plant.*

Global Water Instrumentation Inc., 2007. *Turbidity sensor users guide*, [Online].Available at: http://www.globalw.com [accessed April 2007]

Hydroinformatics Delft, 2000. *Use of artificial neural networks and fuzzy logic for integrated water management.*

Jahan, K., 2003. *Measurement of water quality parameters.*

Juuso, E., Viirret, K. & Piironen, M., 2003. *Intelligent methods in dosing control of water treatment.*

Length counter using pic microcontroller, 2005. (Project report on Arthur C. Clarke institute for modern technologies).

Lind, C., 1994. Coagulation control and optimization: Part One. *Public Works for October*, p.56-57.

Lind, C., 1994. Coagulation control and optimization: Part Two. *Public Works for Novemberr*, p.32-33.

Masson, M.H., Grandvalet, Y. & Lyngaard-Jensen, A., 1999. *Software sensor design based on empirical data ecological modeling.*

Microchip, 2006. *8-bit PIC microcontroller solutions*[Online].Available at: http://www.microchip.com [accessed June 2007].

Mirsepassi, A., Cathers, B. & Dharmappa, H.B., 1995. Application of artificial neural networks to the real time operation of water treatment plants. *In international joint conference on neural networks.*

Pask, D., 1993. Jar testing: Getting started on a low budget, *Technical Brief – spring 2005, Volume 5, Issue 1,* p.5-10.

Trautmann, T. & Denoeux, T., 1995. A constructive algorithm for S.O.M. applied to water quality monitoring. *Intelligent engineering systems through artificial neural networks*, p. 17-22.

Valentin, N., Denoeux, T. & Fotoohi, F., 2000. *Modeling of coagulant dosage in a water treatment plant.*

Valentin, N. & Denoeux, T., 2002. *A neural network-based software sensor for coagulation control in a water treatment plant.*

Appendices

Appendix A	-	Jar Test Results and Calculated Values of Dosages in the Field
Appendix B	-	Final Water Quality for Constructed values of Optimum Values of dosing
Appendix C	-	Development of the Source Code
Appendix D	-	Data base for Turbidity, Optimum Dosage and Angle Movement of Stepper Motor

Appendix-A

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
1	4.0	5.8	7	17.5	5	12.5	7	8.75
2	4.0	6.1	5	12.5	5	12.5	7	8.75
3	4.0	6.4	4	10	5	12.5	7	8.75
4	4.4	7	0	0	5	12.5	8	10
5	4.92	6.5	3	7.5	5	12.5	8	10
6	5.0	5.9	6	15	6	15	7	8.75
7	5.0	6.2	5	12.5	5	12.5	7	8.75
8	5.0	6.5	3	7.5	5	12.5	7	8.75
9	5.3	6.8	0	0	5	12.5	8	10
10	5.4	6.7	3	7.5	5	12.5	8	10
11	5.66	6.7	0	0	5	12.5	7	8.75
12	5.7	7.3	2	5	5	12.5	9	11.25
13	5.8	6.5	3	7.5	5	12.5	9	11.25
14	5.93	6.6	3	7.5	5	12.5	11	13.75
15	6	6.8	4	10	6	15	9	11.25
16	6.0	6	6	15	6	15	7	8.75
17	6.0	6.3	4	10	5	12.5	7	8.75
18	6.0	6.6	3	7.5	5	12.5	7	8.75
19	6.1	6.6	0	0	5	12.5	8	10
20	6.2	6.4	3	7.5	5	12.5	10	12.5
21	6.2	6.6	3	7.5	5	12.5	8	10
22	6.3	6.5	3	7.5	5	12.5	10	12.5
23	6.4	6.6	3	7.5	5	12.5	8	10
24	6.4	6.6	3	7.5	5	12.5	8	10
25	6.5	6.5	3	7.5	5	12.5	10	12.5
26	6.5	6.5	3	7.5	5	12.5	10	12.5
27	6.6	6.6	3	7.5	5	12.5	9	11.25
28	6.8	7.1	0	0	5	12.5	8	10
29	6.8	6.5	3	7.5	5	12.5	10	12.5
30	6.9	6.5	3	7.5	5	12.5	8	10
31	6.9	6.6	3	7.5	5	12.5	10	12.5
32	6.9	6.7	0	0	5	12.5	8	10
33	6.9	6.6	0	0	5	12.5	8	10
34	7	6.9	0	0	6	15	9	11.25
35	7	6.6	3	7.5	5	12.5	10	12.5
36	7	6.6	3	7.5	5	12.5	8	10
37	7.0	6.1	5	12.5	6	15	7	8.75
38	7.0	6.4	4	10	5	12.5	7	8.75
39	7.0	6.7	2	5	5	12.5	7	8.75
40	7.11	6.7	3	7.5	5	12.5	10	12.5
41	7.2	6.9	3	7.5	5	12.5	10	12.5
42	7.3	6.6	3	7.5	5	12.5	8	10
43	7.3	6.5	0	0	5	12.5	8	10

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
44	7.3	6.9	3	7.5	5	12.5	10	12.5
45	7.3	6.9	3	7.5	5	12.5	10	12.5
46	7.3	6.9	3	7.5	5	12.5	10	12.5
47	7.3	6.9	3	7.5	5	12.5	10	12.5
48	7.37	6.5	0	0	6	15	9	11.25
49	7.4	6.9	3	7.5	5	12.5	10	12.5
50	7.4	6.9	3	7.5	5	12.5	10	12.5
51	7.5	6.9	3	7.5	5	12.5	10	12.5
52	7.5	6.9	3	7.5	5	12.5	10	12.5
53	7.5	6.9	3	7.5	5	12.5	10	12.5
54	7.5	6.9	3	7.5	5	12.5	10	12.5
55	7.54	6.5	0	0	6	15	9	11.25
56	7.6	6.4	3	7.5	5	12.5	10	12.5
57	7.6	6.8	3	7.5	5	12.5	10	12.5
58	7.6	6.8	3	7.5	5	12.5	10	12.5
59	7.6	6.9	3	7.5	5	12.5	10	12.5
60	7.7	6.5	3	7.5	5	12.5	9	11.25
61	7.7	6.8	3	7.5	5	12.5	10	12.5
62	7.7	6.8	3	7.5	5	12.5	10	12.5
63	7.7	6.8	3	7.5	5	12.5	10	12.5
64	7.8	6.5	3	7.5	5	12.5	9	11.25
65	7.8	6.5	3	7.5	5	12.5	10	12.5
66	7.9	6.8	0	0	6	15	9	11.25
67	7.9	6.5	3	7.5	5	12.5	9	11.25
68	8.0	6.2	5	12.5	6	15	7	8.75
69	8.0	6.5	3	7.5	5	12.5	7	8.75
70	8.0	6.8	1	2.5	5	12.5	7	8.75
71	8.1	6.5	3	7.5	5	12.5	9	11.25
72	8.1	6.4	4	10	5	12.5	9	11.25
73	8.4	6.5	3	7.5	5	12.5	9	11.25
74	8.6	6.5	3	7.5	5	12.5	10	12.5
75	8.6	6.5	4	10	5	12.5	10	12.5
76	8.6	6.5	3	7.5	5	12.5	9	11.25
77	8.8	6.5	3	7.5	5	12.5	9	11.25
78	9	6.5	3	7.5	5	12.5	10	12.5
79	9.0	6.3	4	10	7	17.5	7	8.75
80	9.0	6.6	3	7.5	5	12.5	7	8.75
81	9.0	6.9	1	2.5	5	12.5	7	8.75
82	9.11	6.5	4	10	5	12.5	9	11.25
83	9.15	6.5	4	10	0	0	11	13.75
84	9.3	6.9	3	7.5	4	10	10	12.5
85	9.9	6.4	4	10	6	15	9	11.25
86	9.98	6.4	4	10	5	12.5	10	12.5

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
87	10.0	6.4	4	10	4	10	7	8.75
88	10.0	6.7	2	5	5	12.5	7	8.75
89	10.0	7	0	0	5	12.5	7	8.75
90	10.3	6.4	4	10	5	12.5	11	13.75
91	10.4	6.4	4	10	5	12.5	9	11.25
92	10.5	6.4	4	10	5	12.5	10	12.5
93	10.5	6.6	2	5	5	12.5	9	11.25
94	10.6	6.5	3	7.5	5	12.5	9	11.25
95	10.6	6.4	4	10	0	0	11	13.75
96	10.8	6.3	4	10	5	12.5	9	11.25
97	10.9	6.5	3	7.5	5	12.5	9	11.25
98	11.0	6.5	3	7.5	5	12.5	7	8.75
99	11.0	6.8	1	2.5	5	12.5	7	8.75
100	11.0	5.8	7	17.5	5	12.5	7	8.75
101	11.2	6.4	4	10	5	12.5	11	13.75
102	11.2	6.4	4	10	5	12.5	11	13.75
103	11.3	6.6	3	7.5	4	10	10	12.5
104	11.5	6.5	3	7.5	5	12.5	9	11.25
105	11.7	6.4	4	10	4	10	11	13.75
106	12	6.5	3	7.5	5	12.5	10	12.5
107	12.0	6.6	3	7.5	6	15	7	8.75
108	12.0	6.9	1	2.5	5	12.5	7	8.75
109	12.0	5.9	6	15	5	12.5	7	8.75
110	12.1	6.5	3	7.5	5	12.5	9	11.25
111	12.1	6.5	3	7.5	6	15	9	11.25
112	12.3	6.4	4	10	5	12.5	9	11.25
113	12.3	6.4	4	10	5	12.5	10	12.5
114	12.5	6.4	5	12.5	6	15	10	12.5
115	12.5	6.3	4	10	4	10	11	13.75
116	12.6	6.5	5	12.5	5	12.5	11	13.75
117	13.0	6.7	2	5	7	17.5	7	8.75
118	13.0	7	0	0	5	12.5	7	8.75
119	13.0	6	6	15	5	12.5	7	8.75
120	13.2	6.6	3	7.5	5	12.5	10	12.5
121	13.2	6.5	3	7.5	5	12.5	10	12.5
122	13.6	6.3	4	10	5	12.5	11	13.75
123	13.6	6.7	0	0	5	12.5	8	10
124	13.7	6.4	4	10	5	12.5	9	11.25
125	13.8	6.5	3	7.5	5	12.5	9	11.25
126	13.9	6.5	3	7.5	5	12.5	9	11.25
127	13.9	6.6	3	7.5	5	12.5	10	12.5
128	14.0	6.8	1	2.5	7	17.5	7	8.75
129	14.0	5.8	7	17.5	5	12.5	7	8.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
130	14.0	6.1	5	12.5	5	12.5	7	8.75
131	14.3	6.4	4	10	0	0	11	13.75
132	14.5	6.4	4	10	5	12.5	9	11.25
133	14.5	6.4	5	12.5	6	15	10	12.5
134	14.8	6.6	4	10	5	12.5	11	13.75
135	15.0	6.9	1	2.5	7	17.5	7	8.75
136	15.0	5.9	6	15	5	12.5	7	8.75
137	15.0	6.2	5	12.5	5	12.5	7	8.75
138	15.1	6.2	5	12.5	5	12.5	10	12.5
139	15.1	6.4	4	10	5	12.5	11	13.75
140	15.1	6.6	4	10	5	12.5	10	12.5
141	15.3	6.8	3	7.5	5	12.5	10	12.5
142	15.3	6.6	3	7.5	5	12.5	10	12.5
143	15.6	6.2	5	12.5	5	12.5	10	12.5
144	16.0	7	0	0	5	12.5	7	8.75
145	16.0	6	6	15	5	12.5	7	8.75
146	16.0	6.3	4	10	5	12.5	7	8.75
147	17.0	5.8	7	17.5	6	15	7	8.75
148	17.0	6.1	5	12.5	5	12.5	7	8.75
149	17.0	6.4	4	10	5	12.5	7	8.75
150	17.5	6.9	3	7.5	5	12.5	12	15
151	17.6	6.4	4	10	5	12.5	11	13.75
152	18	6.3	5	12.5	6	15	10	12.5
153	18.0	5.9	6	15	7	17.5	7	8.75
154	18.0	6.2	5	12.5	5	12.5	7	8.75
155	18.0	6.5	3	7.5	5	12.5	7	8.75
156	18.3	6.4	4	10	5	12.5	10	12.5
157	18.4	6.3	4	10	5	12.5	9	11.25
158	18.4	6.4	4	10	0	0	12	15
159	19.0	6	6	15	6	15	7	8.75
160	19.0	6.3	4	10	5	12.5	7	8.75
161	19.0	6.6	3	7.5	5	12.5	7	8.75
162	19.2	6.5	4	10	5	12.5	11	13.75
163	19.9	6.2	4	10	5	12.5	11	13.75
164	20.0	6.1	5	12.5	5	12.5	7	8.75
165	20.0	6.4	4	10	6	15	7	8.75
166	20.0	6.7	2	5	5	12.5	7	8.75
167	20.4	6.4	4	10	5	12.5	11	13.75
168	20.6	6.4	4	10	5	12.5	10	12.5
169	20.8	6.4	5	12.5	6	15	10	12.5
170	20.9	6.3	4	10	5	12.5	10	12.5
171	21	6.4	4	10	5	12.5	12	15
172	21.0	6.2	5	12.5	5	12.5	7	8.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
173	21.0	6.5	3	7.5	5	12.5	7	8.75
174	21.0	6.8	1	2.5	5	12.5	7	8.75
175	21.2	6.5	4	10	5	12.5	9	11.25
176	21.2	6.5	0	0	6	15	10	12.5
177	21.4	6.3	4	10	5	12.5	11	13.75
178	22	6.9	4	10	5	12.5	10	12.5
179	22.0	6.3	4	10	5	12.5	7	8.75
180	22.0	6.6	3	7.5	5	12.5	7	8.75
181	22.0	6.9	1	2.5	5	12.5	7	8.75
182	22.2	6.4	4	10	5	12.5	12	15
183	22.6	6.4	4	10	0	0	11	13.75
184	22.7	6.6	3	7.5	4	10	10	12.5
185	22.9	6.7	3	7.5	5	12.5	10	12.5
186	23.0	6.4	4	10	6	15	7	8.75
187	23.0	6.7	2	5	5	12.5	7	8.75
188	23.0	7	0	0	5	12.5	7	8.75
189	23.2	6.7	4	10	5	12.5	12	15
190	23.4	6.6	4	10	6	15	13	16.25
191	23.4	6.6	4	10	5	12.5	11	13.75
192	23.5	6.7	4	10	5	12.5	11	13.75
193	23.6	6.7	4	10	5	12.5	11	13.75
194	23.6	6.7	4	10	5	12.5	11	13.75
195	23.6	6.6	4	10	5	12.5	11	13.75
196	23.6	6.7	4	10	5	12.5	11	13.75
197	23.7	6.7	4	10	5	12.5	11	13.75
198	23.7	6.6	4	10	5	12.5	11	13.75
199	23.7	6.7	4	10	5	12.5	11	13.75
200	23.9	6.7	4	10	5	12.5	11	13.75
201	23.9	6.7	5	12.5	6	15	10	12.5
202	24.0	6.5	3	7.5	6	15	7	8.75
203	24.0	6.8	1	2.5	5	12.5	7	8.75
204	24.0	5.8	7	17.5	5	12.5	7	8.75
205	24.1	6.8	4	10	6	15	10	12.5
206	24.2	6.6	4	10	5	12.5	11	13.75
207	24.2	6.6	4	10	5	12.5	11	13.75
208	24.2	6.7	4	10	5	12.5	11	13.75
209	24.2	6.7	5	12.5	6	15	10	12.5
210	24.3	6.7	4	10	5	12.5	10	12.5
211	24.6	6.7	4	10	5	12.5	11	13.75
212	24.8	6.6	4	10	5	12.5	11	13.75
213	25.0	6.6	3	7.5	7	17.5	8	10
214	25.0	6.9	1	2.5	5	12.5	8	10
215	25.0	5.9	6	15	5	12.5	8	10

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
216	25.4	6.6	4	10	5	12.5	11	13.75
217	25.7	6.6	4	10	5	12.5	11	13.75
218	25.8	6.1	5	12.5	8	20	12	15
219	25.9	6.7	5	12.5	6	15	10	12.5
220	26.0	6.7	2	5	6	15	8	10
221	26.0	7	0	0	5	12.5	8	10
222	26.0	6	6	15	5	12.5	8	10
223	27.0	6.8	1	2.5	6	15	8	10
224	27.0	5.8	7	17.5	5	12.5	8	10
225	27.0	6.1	5	12.5	5	12.5	8	10
226	27.1	6.7	5	12.5	6	15	10	12.5
227	27.2	6.4	4	10	5	12.5	12	15
228	27.4	6.4	4	10	5	12.5	9	11.25
229	28	6.4	4	10	0	0	12	15
230	28.0	6.9	1	2.5	5	12.5	8	10
231	28.0	5.9	6	15	4	10	8	10
232	28.0	6.2	5	12.5	6	15	8	10
233	28.1	6.7	4	10	5	12.5	11	13.75
234	28.3	6.7	4	10	5	12.5	11	13.75
235	28.5	6.3	5	12.5	5	12.5	12	15
236	29.0	7	0	0	6	15	8	10
237	29.0	6	6	15	6	15	8	10
238	29.0	6.3	4	10	6	15	8	10
239	29.6	6.7	4	10	5	12.5	11	13.75
240	30.0	5.8	7	17.5	6	15	8	10
241	30.0	6.1	5	12.5	6	15	8	10
242	30.0	6.4	4	10	6	15	8	10
243	30.6	7	4	10	5	12.5	11	13.75
244	30.7	6.5	4	10	5	12.5	10	12.5
245	31	6.3	5	12.5	5	12.5	9	11.25
246	31	6.3	5	12.5	5	12.5	10	12.5
247	31	6.3	4	10	5	12.5	9	11.25
248	31.0	5.9	6	15	6	15	8	10
249	31.0	6.2	5	12.5	6	15	8	10
250	31.0	6.5	3	7.5	6	15	8	10
251	31.2	6.3	4	10	5	12.5	11	13.75
252	31.4	6.3	5	12.5	6	15	12	15
253	32.0	6	6	15	6	15	8	10
254	32.0	6.3	4	10	5	12.5	8	10
255	32.0	6.6	3	7.5	5	12.5	8	10
256	32.9	6.3	5	12.5	6	15	12	15
257	33.0	6.1	5	12.5	6	15	8	10
258	33.0	6.4	4	10	6	15	8	10

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
259	33.0	6.7	2	5	6	15	8	10
260	34.0	6.2	5	12.5	6	15	8	10
261	34.0	6.5	3	7.5	6	15	8	10
262	34.0	6.8	1	2.5	6	15	8	10
263	35.0	6.3	4	10	6	15	8	10
264	35.0	6.6	3	7.5	6	15	8	10
265	35.0	6.9	1	2.5	6	15	8	10
266	35.5	6.5	4	10	5	12.5	11	13.75
267	36.0	6.4	4	10	6	15	8	10
268	36.0	6.7	2	5	6	15	8	10
269	36.0	7	0	0	6	15	8	10
270	37.0	6.5	3	7.5	6	15	8	10
271	37.0	6.8	1	2.5	5	12.5	8	10
272	37.0	5.8	7	17.5	7	17.5	8	10
273	37.2	6.5	4	10	5	12.5	11	13.75
274	37.4	6.5	4	10	5	12.5	11	13.75
275	37.8	6.6	5	12.5	5	12.5	12	15
276	38.0	6.6	3	7.5	6	15	8	10
277	38.0	6.9	1	2.5	5	12.5	8	10
278	38.0	5.9	6	15	4	10	8	10
279	38.5	6.5	4	10	5	12.5	11	13.75
280	39.0	6.7	2	5	6	15	8	10
281	39.0	7	0	0	6	15	8	10
282	39.0	6	6	15	5	12.5	8	10
283	40.0	6.8	1	2.5	6	15	8	10
284	40.0	5.8	7	17.5	6	15	8	10
285	40.0	6.1	5	12.5	6	15	8	10
286	40.1	6.5	4	10	5	12.5	11	13.75
287	41.0	6.9	1	2.5	6	15	8	10
288	41.0	5.9	6	15	6	15	8	10
289	41.0	6.2	5	12.5	7	17.5	8	10
290	41.2	6.5	4	10	5	12.5	11	13.75
291	41.4	6.5	4	10	5	12.5	11	13.75
292	41.7	6.8	3	7.5	5	12.5	10	12.5
293	41.9	6.7	4	10	5	12.5	11	13.75
294	42.0	7	0	0	6	15	8	10
295	42.0	6	6	15	5	12.5	8	10
296	42.0	6.3	4	10	7	17.5	8	10
297	43.0	6.5	4	10	5	12.5	11	13.75
298	43.0	5.8	7	17.5	6	15	8	10
299	43.0	6.1	5	12.5	5	12.5	8	10
300	43.0	6.4	4	10	7	17.5	8	10
301	43.7	6.5	4	10	5	12.5	11	13.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
302	44.0	5.9	6	15	6	15	8	10
303	44.0	6.2	5	12.5	5	12.5	8	10
304	44.0	6.5	3	7.5	5	12.5	8	10
305	45	6.5	5	12.5	6	15	14	17.5
306	45.0	6	6	15	6	15	8	10
307	45.0	6.3	4	10	5	12.5	8	10
308	45.0	6.6	3	7.5	6	15	8	10
309	45.8	6.5	4	10	5	12.5	11	13.75
310	46	6.5	5	12.5	5	12.5	10	12.5
311	46.0	6.1	5	12.5	6	15	8	10
312	46.0	6.4	4	10	5	12.5	8	10
313	46.0	6.7	2	5	7	17.5	8	10
314	47.0	6.2	5	12.5	6	15	9	11.25
315	47.0	6.5	3	7.5	5	12.5	9	11.25
316	47.0	6.8	1	2.5	6	15	9	11.25
317	48.0	6.3	4	10	6	15	9	11.25
318	48.0	6.6	3	7.5	5	12.5	9	11.25
319	48.0	6.9	1	2.5	5	12.5	9	11.25
320	49.0	6.4	4	10	6	15	9	11.25
321	49.0	6.7	2	5	5	12.5	9	11.25
322	49.0	7	0	0	5	12.5	9	11.25
323	49.3	6.5	4	10	5	12.5	11	13.75
324	50.0	6.5	3	7.5	6	15	9	11.25
325	50.0	6.8	1	2.5	6	15	9	11.25
326	50.0	5.8	7	17.5	5	12.5	9	11.25
327	51.0	6.6	3	7.5	6	15	9	11.25
328	51.0	6.9	1	2.5	6	15	9	11.25
329	51.0	5.9	6	15	6	15	9	11.25
330	52.0	6.7	2	5	6	15	9	11.25
331	52.0	7	0	0	6	15	9	11.25
332	52.0	6	6	15	6	15	9	11.25
333	52.1	6.6	4	10	5	12.5	12	15
334	52.4	6.6	4	10	5	12.5	12	15
335	52.8	6.3	4	10	5	12.5	12	15
336	53.0	6.8	1	2.5	6	15	9	11.25
337	53.0	5.8	7	17.5	6	15	9	11.25
338	53.0	6.1	5	12.5	7	17.5	9	11.25
339	54.0	6.9	1	2.5	6	15	9	11.25
340	54.0	5.9	6	15	6	15	9	11.25
341	54.0	6.2	5	12.5	6	15	9	11.25
342	54.2	6.6	4	10	5	12.5	12	15
343	54.3	6.6	4	10	5	12.5	12	15
344	55.0	6.6	4	10	5	12.5	12	15

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
345	55.0	7	0	0	6	15	9	11.25
346	55.0	6	6	15	6	15	9	11.25
347	55.0	6.3	4	10	6	15	9	11.25
348	55.4	6.5	4	10	5	12.5	12	15
349	56.0	5.8	7	17.5	7	17.5	9	11.25
350	56.0	6.1	5	12.5	6	15	9	11.25
351	56.0	6.4	4	10	5	12.5	9	11.25
352	57.0	6.5	4	10	5	12.5	11	13.75
353	57.0	5.9	6	15	6	15	9	11.25
354	57.0	6.2	5	12.5	6	15	9	11.25
355	57.0	6.5	3	7.5	6	15	9	11.25
356	57.3	6.8	4	10	5	12.5	11	13.75
357	58.0	6	6	15	6	15	9	11.25
358	58.0	6.3	4	10	6	15	9	11.25
359	58.0	6.6	3	7.5	6	15	9	11.25
360	58.2	6.7	4	10	5	12.5	11	13.75
361	59	6.1	5	12.5	0	0	14	17.5
362	59.0	6.1	5	12.5	5	12.5	9	11.25
363	59.0	6.4	4	10	6	15	9	11.25
364	59.0	6.7	2	5	6	15	9	11.25
365	59.1	6.4	4	10	5	12.5	12	15
366	59.6	6.6	4	10	5	12.5	12	15
367	60.0	6.4	7	17.5	7.0	17.5	18.0	22.5
368	60.0	6.4	7	17.5	7.0	17.5	18.0	22.5
369	60.0	6.4	7	17.5	7.0	17.5	18.0	22.5
370	60.0	6.2	5	12.5	5	12.5	9	11.25
371	60.0	6.5	3	7.5	5	12.5	9	11.25
372	60.0	6.8	1	2.5	6	15	9	11.25
373	61	6.4	4	10	5	12.5	12	15
374	61.0	6.3	4	10	5	12.5	9	11.25
375	61.0	6.6	3	7.5	5	12.5	9	11.25
376	61.0	6.9	1	2.5	6	15	9	11.25
377	61.6	6.4	4	10	6	15	12	15
378	62.0	6.4	4	10	5	12.5	9	11.25
379	62.0	6.7	2	5	5	12.5	9	11.25
380	62.0	7	0	0	6	15	9	11.25
381	63.0	6.3	7	17.5	7.0	17.5	18.0	22.5
382	63.0	6.5	3	7.5	5	12.5	9	11.25
383	63.0	6.8	1	2.5	5	12.5	9	11.25
384	63.0	5.8	7	17.5	6	15	9	11.25
385	64.0	6.3	7	17.5	7.0	17.5	18.0	22.5
386	64.0	6.6	3	7.5	6	15	9	11.25
387	64.0	6.9	1	2.5	5	12.5	9	11.25

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
388	64.0	5.9	6	15	6	15	9	11.25
389	65.0	6.7	2	5	6	15	9	11.25
390	65.0	7	0	0	5	12.5	9	11.25
391	65.0	6	6	15	6	15	9	11.25
392	65.1	6.6	4	10	5	12.5	12	15
393	66.0	6.8	1	2.5	6	15	9	11.25
394	66.0	5.8	7	17.5	5	12.5	9	11.25
395	66.0	6.1	5	12.5	6	15	9	11.25
396	66.1	6.6	4	10	6.0	15	13.0	16.25
397	66.4	6.5	4	10	5	12.5	12	15
398	67.0	6.3	7	17.5	7.0	17.5	18.0	22.5
399	67.0	6.9	1	2.5	7	17.5	9	11.25
400	67.0	5.9	6	15	5	12.5	9	11.25
401	67.0	6.2	5	12.5	6	15	9	11.25
402	68.0	7	0	0	7	17.5	9	11.25
403	68.0	6	6	15	5	12.5	9	11.25
404	68.0	6.3	4	10	6	15	9	11.25
405	69.0	5.8	7	17.5	5	12.5	9	11.25
406	69.0	6.1	5	12.5	5	12.5	9	11.25
407	69.0	6.4	4	10	6	15	9	11.25
408	70.0	5.9	6	15	5	12.5	10	12.5
409	70.0	6.2	5	12.5	5	12.5	10	12.5
410	70.0	6.5	3	7.5	6	15	10	12.5
411	70.1	6.4	3	7.5	5	12.5	11	13.75
412	71.0	6	6	15	6	15	10	12.5
413	71.0	6.3	4	10	5	12.5	10	12.5
414	71.0	6.6	3	7.5	6	15	10	12.5
415	71.9	6.4	6	15	7	17.5	13	16.25
416	72.0	6.1	5	12.5	6	15	10	12.5
417	72.0	6.4	4	10	5	12.5	10	12.5
418	72.0	6.7	2	5	6	15	10	12.5
419	73.0	6.3	7	17.5	7.0	17.5	18.0	22.5
420	73.0	6.2	5	12.5	6	15	10	12.5
421	73.0	6.5	3	7.5	5	12.5	10	12.5
422	73.0	6.8	1	2.5	6	15	10	12.5
423	73.2	6.6	4	10	5	12.5	12	15
424	74.0	6.3	4	10	5	12.5	10	12.5
425	74.0	6.6	3	7.5	5	12.5	10	12.5
426	74.0	6.9	1	2.5	6	15	10	12.5
427	75.0	6.4	4	10	6	15	10	12.5
428	75.0	6.7	2	5	5	12.5	10	12.5
429	75.0	7	0	0	6	15	10	12.5
430	76.0	6.5	3	7.5	6	15	10	12.5

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
431	76.0	6.8	1	2.5	5	12.5	10	12.5
432	76.0	5.8	7	17.5	6	15	10	12.5
433	76.1	6.5	4	10	5	12.5	12	15
434	76.4	6.6	4	10	5	12.5	13	16.25
435	77	6	7	17.5	7	17.5	14	17.5
436	77.0	6.5	5	12.5	6	15	10	12.5
437	77.0	6.6	3	7.5	0	0	10	12.5
438	77.0	6.9	1	2.5	6	15	10	12.5
439	77.0	5.9	6	15	6	15	10	12.5
440	78.0	6.7	2	5	6	15	10	12.5
441	78.0	7	0	0	6	15	10	12.5
442	78.0	6	6	15	6	15	10	12.5
443	79.0	6.8	1	2.5	6	15	10	12.5
444	79.0	5.8	7	17.5	6	15	10	12.5
445	79.0	6.1	5	12.5	6	15	10	12.5
446	79.2	6.5	4	10	5	12.5	14	17.5
447	80.0	6.9	1	2.5	7	17.5	10	12.5
448	80.0	5.9	6	15	7	17.5	10	12.5
449	80.0	6.2	5	12.5	6	15	10	12.5
450	80.2	6.5	5	12.5	6	15	10	12.5
451	81.0	7	0	0	5	12.5	10	12.5
452	81.0	6	6	15	8	20	10	12.5
453	81.0	6.3	4	10	6	15	10	12.5
454	82.0	5.8	7	17.5	6	15	10	12.5
455	82.0	6.1	5	12.5	5	12.5	10	12.5
456	82.0	6.4	4	10	6	15	10	12.5
457	83.0	5.9	6	15	6	15	10	12.5
458	83.0	6.2	5	12.5	4	10	10	12.5
459	83.0	6.5	3	7.5	6	15	10	12.5
460	84.0	6	6	15	5	12.5	10	12.5
461	84.0	6.3	4	10	5	12.5	10	12.5
462	84.0	6.6	3	7.5	7	17.5	10	12.5
463	85.0	6.1	5	12.5	7	17.5	10	12.5
464	85.0	6.4	4	10	5	12.5	10	12.5
465	85.0	6.7	2	5	6	15	10	12.5
466	85.7	6.5	5	12.5	6	15	10	12.5
467	86.0	6.3	7	17.5	7.0	17.5	18.0	22.5
468	86.0	6.2	5	12.5	5	12.5	10	12.5
469	86.0	6.5	3	7.5	4	10	10	12.5
470	86.0	6.8	1	2.5	6	15	10	12.5
471	86.4	6.5	4	10	5	12.5	14	17.5
472	87.0	6.3	4	10	6	15	10	12.5
473	87.0	6.6	3	7.5	5	12.5	10	12.5

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
474	87.0	6.9	1	2.5	5	12.5	10	12.5
475	87.9	6.8	4	10	5	12.5	11	13.75
476	88.0	6.4	4	10	7	17.5	10	12.5
477	88.0	6.7	2	5	5	12.5	10	12.5
478	88.0	7	0	0	5	12.5	10	12.5
479	89.0	6.6	4	10	6.0	15	13.0	16.25
480	89.0	6.5	3	7.5	5	12.5	10	12.5
481	89.0	6.8	1	2.5	5	12.5	10	12.5
482	89.0	5.8	7	17.5	5	12.5	10	12.5
483	90	6.5	5	12.5	6	15	15	18.75
484	90.0	6.6	3	7.5	6	15	10	12.5
485	90.0	6.9	1	2.5	5	12.5	10	12.5
486	90.0	5.9	6	15	5	12.5	10	12.5
487	91.0	6.7	2	5	7	17.5	10	12.5
488	91.0	7	0	0	5	12.5	10	12.5
489	91.0	6	6	15	5	12.5	10	12.5
490	91.3	6.5	5	12.5	6	15	10	12.5
491	92.0	6.8	1	2.5	5	12.5	11	13.75
492	92.0	5.8	7	17.5	5	12.5	11	13.75
493	92.0	6.1	5	12.5	6	15	11	13.75
494	93.0	6.9	1	2.5	5	12.5	11	13.75
495	93.0	5.9	6	15	5	12.5	11	13.75
496	93.0	6.2	5	12.5	6	15	11	13.75
497	93.4	6.6	4	10	6	15	13	16.25
498	93.4	6.5	4	10	5	12.5	14	17.5
499	94.0	6.4	5	12.5	5	12.5	14	17.5
500	94.0	7	0	0	6	15	11	13.75
501	94.0	6	6	15	5	12.5	11	13.75
502	94.0	6.3	4	10	6	15	11	13.75
503	94.1	6.5	4	10	5	12.5	13	16.25
504	95.0	6.2	7	17.5	7.0	17.5	18.0	22.5
505	95.0	5.8	7	17.5	6	15	11	13.75
506	95.0	6.1	5	12.5	5	12.5	11	13.75
507	95.0	6.4	4	10	7	17.5	11	13.75
508	96.0	5.9	6	15	5	12.5	11	13.75
509	96.0	6.2	5	12.5	0	0	11	13.75
510	96.0	6.5	3	7.5	7	17.5	11	13.75
511	97	6.2	4	10	5	12.5	12	15
512	97.0	6	6	15	6	15	11	13.75
513	97.0	6.3	4	10	0	0	11	13.75
514	97.0	6.6	3	7.5	5	12.5	11	13.75
515	98.0	6.4	5	12.5	5	12.5	14	17.5
516	98.0	6.1	5	12.5	7	17.5	11	13.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
517	98.0	6.4	4	10	0	0	11	13.75
518	98.0	6.7	2	5	5	12.5	11	13.75
519	99.0	6.2	5	12.5	0	0	11	13.75
520	99.0	6.5	3	7.5	0	0	11	13.75
521	99.0	6.8	1	2.5	6	15	11	13.75
522	100.0	6.3	4	10	6	15	11	13.75
523	100.0	6.6	3	7.5	0	0	11	13.75
524	100.0	6.9	1	2.5	6	15	11	13.75
525	101.0	6.5	4	10	5	12.5	11	13.75
526	101.0	6.4	4	10	7	17.5	11	13.75
527	101.0	6.7	2	5	0	0	11	13.75
528	101.0	7	0	0	6	15	11	13.75
529	102	6.5	5	12.5	6	15	16	20
530	102.0	6.5	3	7.5	7	17.5	11	13.75
531	102.0	6.8	1	2.5	0	0	11	13.75
532	102.0	5.8	7	17.5	5	12.5	11	13.75
533	103.0	6.6	3	7.5	7	17.5	11	13.75
534	103.0	6.9	1	2.5	4	10	11	13.75
535	103.0	5.9	6	15	6	15	11	13.75
536	104	6.4	5	12.5	6	15	13	16.25
537	104.0	6.7	2	5	5	12.5	11	13.75
538	104.0	7	0	0	4	10	11	13.75
539	104.0	6	6	15	6	15	11	13.75
540	105.0	6.5	4	10	5	12.5	11	13.75
541	105.0	6.8	1	2.5	5	12.5	11	13.75
542	105.0	5.8	7	17.5	5	12.5	11	13.75
543	105.0	6.1	5	12.5	0	0	11	13.75
544	106.0	6.9	1	2.5	5	12.5	11	13.75
545	106.0	5.9	6	15	5	12.5	11	13.75
546	106.0	6.2	5	12.5	6	15	11	13.75
547	107.0	7	0	0	5	12.5	11	13.75
548	107.0	6	6	15	5	12.5	11	13.75
549	107.0	6.3	4	10	6	15	11	13.75
550	108.0	6.5	4	10	5	12.5	14	17.5
551	108.0	5.8	7	17.5	5	12.5	11	13.75
552	108.0	6.1	5	12.5	5	12.5	11	13.75
553	108.0	6.4	4	10	7	17.5	11	13.75
554	109	6.6	4	10	5	12.5	14	17.5
555	109.0	6.2	7	17.5	7.0	17.5	18.0	22.5
556	109.0	5.9	6	15	7	17.5	11	13.75
557	109.0	6.2	5	12.5	5	12.5	11	13.75
558	109.0	6.5	3	7.5	5	12.5	11	13.75
559	110	6.1	5	12.5	5	12.5	13	16.25

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
560	110.0	6	6	15	7	17.5	11	13.75
561	110.0	6.3	4	10	5	12.5	11	13.75
562	110.0	6.6	3	7.5	6	15	11	13.75
563	111.0	6.1	5	12.5	7	17.5	11	13.75
564	111.0	6.4	4	10	5	12.5	11	13.75
565	111.0	6.7	2	5	6	15	11	13.75
566	112.0	6.5	4	10	5	12.5	11	13.75
567	112.0	6.2	5	12.5	6	15	11	13.75
568	112.0	6.5	3	7.5	5	12.5	11	13.75
569	112.0	6.8	1	2.5	5	12.5	11	13.75
570	113	6.5	4	10	5	12.5	13	16.25
571	113.0	6.3	4	10	5	12.5	11	13.75
572	113.0	6.6	3	7.5	5	12.5	11	13.75
573	113.0	6.9	1	2.5	7	17.5	11	13.75
574	114.0	6.5	4	10	5	12.5	14	17.5
575	114.0	6.4	4	10	6	15	12	15
576	114.0	6.7	2	5	5	12.5	12	15
577	114.0	7	0	0	5	12.5	12	15
578	115.0	6.5	4	10	5	12.5	11	13.75
579	115.0	6.5	3	7.5	6	15	12	15
580	115.0	6.8	1	2.5	5	12.5	12	15
581	115.0	7.1	7	17.5	6	15	12	15
582	116.0	6.6	3	7.5	6	15	12	15
583	116.0	6.9	1	2.5	5	12.5	12	15
584	116.0	7.2	6	15	7	17.5	12	15
585	117	6.4	4	10	5	12.5	12	15
586	117.0	6.7	2	5	6	15	12	15
587	117.0	7	0	0	5	12.5	12	15
588	117.0	7.3	6	15	5	12.5	12	15
589	118	6.5	5	12.5	6	15	14.5	18.13
590	118.0	6.5	4	10	5	12.5	11	13.75
591	118.0	6.8	1	2.5	5	12.5	12	15
592	118.0	5.8	7	17.5	5	12.5	12	15
593	118.0	5.8	5	12.5	6	15	12	15
594	119.0	6.9	1	2.5	5	12.5	12	15
595	119.0	5.9	6	15	5	12.5	12	15
596	119.0	5.9	5	12.5	7	17.5	12	15
597	120.0	6.4	5	12.5	5	12.5	14	17.5
598	120.0	7	0	0	5	12.5	12	15
599	120.0	6	6	15	5	12.5	12	15
600	121.0	5.8	7	17.5	5	12.5	12	15
601	121.0	6.1	5	12.5	5	12.5	12	15
602	122.0	5.9	6	15	5	12.5	12	15

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
603	122.0	6.2	5	12.5	5	12.5	12	15
604	123	6.5	5	12.5	6	15	14	17.5
605	123.0	6.5	4	10	5	12.5	11	13.75
606	123.0	6	6	15	5	12.5	12	15
607	123.0	6.3	4	10	5	12.5	12	15
608	124	6.5	5	12.5	6	15	16	20
609	124	6.5	5	12.5	6	15	16	20
610	124	6.4	5	12.5	6	15	15	18.75
611	124.0	6.5	4	10	5	12.5	14	17.5
612	124.0	6.2	7	17.5	7.0	17.5	18.0	22.5
613	124.0	6.1	5	12.5	5	12.5	12	15
614	124.0	6.4	4	10	5	12.5	12	15
615	125	6	6	15	6	15	14	17.5
616	125	6.6	4	10	6	15	14	17.5
617	125.0	6.7	4	10	5	12.5	12	15
618	125.0	6.2	5	12.5	5	12.5	12	15
619	125.0	6.5	3	7.5	5	12.5	12	15
620	126.0	6.4	5	12.5	5	12.5	14	17.5
621	126.0	6.3	4	10	5	12.5	12	15
622	126.0	6.6	3	7.5	5	12.5	12	15
623	127.0	6.4	4	10	5	12.5	12	15
624	127.0	6.7	2	5	5	12.5	12	15
625	128.0	6.5	4	10	5	12.5	11	13.75
626	128.0	6.5	3	7.5	5	12.5	12	15
627	128.0	6.8	1	2.5	5	12.5	12	15
628	129.0	6.4	5	12.5	5	12.5	14	17.5
629	129.0	6.6	3	7.5	5	12.5	12	15
630	129.0	6.9	1	2.5	5	12.5	12	15
631	130.0	6.5	4	10	5	12.5	14	17.5
632	130.0	6.7	2	5	5	12.5	12	15
633	130.0	7	0	0	5	12.5	12	15
634	131.0	6.5	4	10	5	12.5	14	17.5
635	131.0	6.8	1	2.5	5	12.5	12	15
636	131.0	5.8	7	17.5	5	12.5	12	15
637	132	6.4	5	12.5	6	15	15	18.75
638	132.0	6.4	5	12.5	5	12.5	14	17.5
639	132.0	6.9	1	2.5	5	12.5	12	15
640	132.0	5.9	6	15	5	12.5	12	15
641	133.0	6.5	4	10	5	12.5	14	17.5
642	133.0	7	0	0	5	12.5	12	15
643	133.0	6	6	15	5	12.5	12	15
644	134.0	5.8	7	17.5	5	12.5	12	15
645	134.0	6.1	5	12.5	6	15	12	15

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
646	135.0	5.9	6	15	6	15	12	15
647	135.0	6.2	5	12.5	5	12.5	12	15
648	136.0	6.5	4	10	5	12.5	14	17.5
649	136.0	6	6	15	6	15	12	15
650	136.0	6.3	4	10	5	12.5	12	15
651	137.0	6.1	5	12.5	6	15	13	16.25
652	137.0	6.4	4	10	6	15	13	16.25
653	138.0	6.2	5	12.5	5	12.5	13	16.25
654	138.0	6.5	3	7.5	6	15	13	16.25
655	139	6.2	6	15	7	17.5	17	21.25
656	139	6.2	6	15	7	17.5	17	21.25
657	139.0	6.2	7	17.5	7.0	17.5	18.0	22.5
658	139.0	6.4	5	12.5	6	15	15	18.75
659	139.0	6.5	4	10	5	12.5	11	13.75
660	139.0	6.3	4	10	5	12.5	13	16.25
661	139.0	6.6	3	7.5	6	15	13	16.25
662	140.0	6.4	4	10	5	12.5	13	16.25
663	140.0	6.7	2	5	5	12.5	13	16.25
664	141.0	6.5	3	7.5	5	12.5	13	16.25
665	141.0	6.8	1	2.5	5	12.5	13	16.25
666	142.0	6.5	4	10	5	12.5	11	13.75
667	142.0	6.6	3	7.5	6	15	13	16.25
668	142.0	6.9	1	2.5	5	12.5	13	16.25
669	143	6.5	6	15	5	12.5	14	17.5
670	143	6.5	5	12.5	5	12.5	14.5	18.13
671	143.0	6.7	2	5	6	15	13	16.25
672	143.0	7	0	0	5	12.5	13	16.25
673	144	6.4	6	15	5	12.5	14.5	18.13
674	144.0	6.8	1	2.5	6	15	13	16.25
675	144.0	5.8	7	17.5	5	12.5	13	16.25
676	145	6.3	5	12.5	5	12.5	16	20
677	145.0	6.9	1	2.5	6	15	13	16.25
678	145.0	5.9	6	15	5	12.5	13	16.25
679	146.0	7	0	0	6	15	13	16.25
680	146.0	6	6	15	5	12.5	13	16.25
681	147.0	5.8	7	17.5	6	15	13	16.25
682	147.0	6.1	5	12.5	5	12.5	13	16.25
683	148	6.6	5	12.5	6	15	16	20
684	148	6.3	6	15	5	12.5	16	20
685	148.0	5.9	6	15	6	15	13	16.25
686	148.0	6.2	5	12.5	5	12.5	13	16.25
687	149.0	6	6	15	6	15	13	16.25
688	149.0	6.3	4	10	5	12.5	13	16.25

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
689	150	5.8	7	17.5	6	15	14.5	18.13
690	150.0	6.1	5	12.5	6	15	13	16.25
691	150.0	6.4	4	10	5	12.5	13	16.25
692	151.0	6.2	5	12.5	6	15	13	16.25
693	151.0	6.5	3	7.5	5	12.5	13	16.25
694	152.0	6.3	4	10	6	15	13	16.25
695	152.0	6.6	3	7.5	5	12.5	13	16.25
696	153.0	6.4	4	10	6	15	13	16.25
697	153.0	6.7	2	5	5	12.5	13	16.25
698	154.0	6.5	3	7.5	6	15	13	16.25
699	154.0	6.8	1	2.5	5	12.5	13	16.25
700	155	6.4	4	10	5	12.5	14	17.5
701	155.0	6.2	7	17.5	7.0	17.5	18.0	22.5
702	155.0	6.6	3	7.5	6	15	13	16.25
703	155.0	6.9	1	2.5	5	12.5	13	16.25
704	156.0	6.5	4	10	5	12.5	14	17.5
705	156.0	6.7	2	5	6	15	13	16.25
706	156.0	7	0	0	6	15	13	16.25
707	157.0	6.8	1	2.5	6	15	13	16.25
708	157.0	5.8	7	17.5	6	15	13	16.25
709	158	6.6	5	12.5	5	12.5	16	20
710	158.0	6.9	1	2.5	6	15	13	16.25
711	158.0	5.9	6	15	7	17.5	13	16.25
712	159	6.5	4	10	5	12.5	14	17.5
713	159.0	6.5	4	10	5	12.5	14	17.5
714	159.0	6.6	4	10	6.0	15	14.0	17.5
715	159.0	7	0	0	5	12.5	14	17.5
716	159.0	6	6	15	6	15	14	17.5
717	160.0	5.8	7	17.5	5	12.5	14	17.5
718	160.0	6.1	5	12.5	6	15	14	17.5
719	161.0	5.9	6	15	5	12.5	14	17.5
720	161.0	6.2	5	12.5	7	17.5	14	17.5
721	162.0	6	6	15	5	12.5	14	17.5
722	162.0	6.3	4	10	7	17.5	14	17.5
723	163.0	6.1	5	12.5	5	12.5	14	17.5
724	163.0	6.4	4	10	6	15	14	17.5
725	164	6.6	4	10	5	12.5	14	17.5
726	164.0	6.2	5	12.5	5	12.5	14	17.5
727	164.0	6.5	3	7.5	7	17.5	14	17.5
728	165.0	6.3	4	10	6	15	14	17.5
729	165.0	6.6	3	7.5	6	15	14	17.5
730	166.0	6.4	4	10	6	15	14	17.5
731	166.0	6.7	2	5	6	15	14	17.5

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
732	167.0	6.5	3	7.5	7	17.5	14	17.5
733	167.0	6.8	1	2.5	6	15	14	17.5
734	168	6.5	5	12.5	6	15	16	20
735	168.0	6.5	4	10	5	12.5	11	13.75
736	168.0	6.6	3	7.5	7	17.5	14	17.5
737	168.0	6.9	1	2.5	6	15	14	17.5
738	169.0	6.1	7	17.5	7.0	17.5	18.0	22.5
739	169.0	6.4	5	12.5	6	15	15	18.75
740	169.0	6.7	2	5	6	15	14	17.5
741	169.0	7	0	0	5	12.5	14	17.5
742	170.0	6.8	1	2.5	6	15	14	17.5
743	170.0	5.8	7	17.5	5	12.5	14	17.5
744	171	6.4	6	15	5	12.5	16	20
745	171.0	6.9	1	2.5	6	15	14	17.5
746	171.0	5.9	6	15	5	12.5	14	17.5
747	172.0	7	0	0	6	15	14	17.5
748	172.0	6	6	15	5	12.5	14	17.5
749	173	6.3	6	15	5	12.5	18	22.5
750	173.0	5.8	7	17.5	6	15	14	17.5
751	173.0	6.1	5	12.5	5	12.5	14	17.5
752	174.0	5.9	6	15	6	15	14	17.5
753	174.0	6.2	5	12.5	5	12.5	14	17.5
754	175.0	6	6	15	7	17.5	14	17.5
755	175.0	6.3	4	10	5	12.5	14	17.5
756	176	5.9	7	17.5	6	15	14.5	18.13
757	176.0	6.1	5	12.5	7	17.5	14	17.5
758	176.0	6.4	4	10	5	12.5	14	17.5
759	177.0	6.2	5	12.5	7	17.5	14	17.5
760	177.0	6.5	3	7.5	5	12.5	14	17.5
761	178.0	6.3	4	10	5	12.5	14	17.5
762	178.0	6.6	3	7.5	5	12.5	14	17.5
763	179.0	6.6	4	10	5	12.5	12	15
764	179.0	6.4	4	10	5	12.5	14	17.5
765	179.0	6.7	2	5	5	12.5	14	17.5
766	180.0	6.5	3	7.5	6	15	14	17.5
767	180.0	6.8	1	2.5	5	12.5	14	17.5
768	181.0	6.6	3	7.5	6	15	15	18.75
769	181.0	6.9	1	2.5	5	12.5	15	18.75
770	182.0	6.2	7	17.5	7.0	17.5	18.0	22.5
771	182.0	6.7	2	5	6	15	15	18.75
772	182.0	7	0	0	5	12.5	15	18.75
773	183.0	6.8	1	2.5	6	15	15	18.75
774	183.0	5.8	7	17.5	5	12.5	15	18.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
775	184.0	6.9	1	2.5	6	15	15	18.75
776	184.0	5.9	6	15	5	12.5	15	18.75
777	185.0	7	0	0	6	15	15	18.75
778	185.0	6	6	15	5	12.5	15	18.75
779	186.0	5.8	7	17.5	6	15	15	18.75
780	186.0	6.1	5	12.5	5	12.5	15	18.75
781	187.0	5.9	6	15	6	15	15	18.75
782	187.0	6.2	5	12.5	5	12.5	15	18.75
783	188.0	6.4	5	12.5	6	15	15	18.75
784	188.0	6	6	15	6	15	15	18.75
785	188.0	6.3	4	10	5	12.5	15	18.75
786	189.0	6.1	5	12.5	6	15	15	18.75
787	189.0	6.4	4	10	5	12.5	15	18.75
788	190.0	6.2	5	12.5	6	15	15	18.75
789	190.0	6.5	3	7.5	5	12.5	15	18.75
790	191	6.2	7	17.5	7	17.5	18	22.5
791	191.0	6.2	7	17.5	7.0	17.5	18.0	22.5
792	191.0	6.3	4	10	6	15	15	18.75
793	191.0	6.6	3	7.5	6	15	15	18.75
794	192.0	6.4	4	10	6	15	15	18.75
795	192.0	6.7	2	5	6	15	15	18.75
796	193.0	6.5	3	7.5	6	15	15	18.75
797	193.0	6.8	1	2.5	6	15	15	18.75
798	194.0	6.6	3	7.5	6	15	15	18.75
799	194.0	6.9	1	2.5	6	15	15	18.75
800	195.0	6.4	5	12.5	6	15	15	18.75
801	195.0	6.7	2	5	6	15	15	18.75
802	195.0	7	0	0	5	12.5	15	18.75
803	196.0	6.8	1	2.5	6	15	15	18.75
804	196.0	5.8	7	17.5	5	12.5	15	18.75
805	197	6.2	5	12.5	6	15	14	17.5
806	197.0	6.9	1	2.5	6	15	15	18.75
807	197.0	5.9	6	15	5	12.5	15	18.75
808	198.0	7	0	0	6	15	15	18.75
809	198.0	6	6	15	5	12.5	15	18.75
810	199.0	5.8	7	17.5	6	15	15	18.75
811	199.0	6.1	5	12.5	5	12.5	15	18.75
812	200	6.5	5	12.5	5	12.5	16	20
813	200.0	6.2	7	17.5	7.0	17.5	18.0	22.5
814	200.0	5.9	6	15	6	15	15	18.75
815	200.0	6.2	5	12.5	5	12.5	15	18.75
816	200.8	6.5	4	10	6	15	11	13.75
817	201.0	6	6	15	6	15	15	18.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
818	201.0	6.3	4	10	5	12.5	15	18.75
819	202.0	6.1	5	12.5	6	15	15	18.75
820	202.0	6.4	4	10	5	12.5	15	18.75
821	203	6.3	6	15	6	15	16	20
822	203.0	6.2	5	12.5	6	15	15	18.75
823	203.0	6.5	3	7.5	5	12.5	15	18.75
824	204.0	6.4	5	12.5	6.0	15	14.5	18.13
825	204.0	6.3	4	10	5	12.5	16	20
826	204.0	6.6	3	7.5	5	12.5	16	20
827	205.0	6.4	4	10	5	12.5	16	20
828	205.0	6.7	2	5	5	12.5	16	20
829	206.0	6.5	3	7.5	5	12.5	16	20
830	206.0	6.8	1	2.5	5	12.5	16	20
831	207.0	6.6	3	7.5	5	12.5	16	20
832	207.0	6.9	1	2.5	5	12.5	16	20
833	208.0	6.7	2	5	7	17.5	16	20
834	208.0	7	0	0	5	12.5	16	20
835	209	6.4	5	12.5	6	15	16	20
836	209.0	6.8	1	2.5	7	17.5	16	20
837	209.0	5.8	7	17.5	5	12.5	16	20
838	210.0	6.9	1	2.5	7	17.5	16	20
839	210.0	5.9	6	15	5	12.5	16	20
840	211.0	7	0	0	7	17.5	16	20
841	211.0	6	6	15	5	12.5	16	20
842	212.0	5.8	7	17.5	6	15	16	20
843	212.0	6.1	5	12.5	5	12.5	16	20
844	213.0	5.9	6	15	5	12.5	16	20
845	213.0	6.2	5	12.5	5	12.5	16	20
846	214.0	6.5	4	10	5	12.5	12	15
847	214.0	6	6	15	7	17.5	16	20
848	214.0	6.3	4	10	5	12.5	16	20
849	215.0	6.1	5	12.5	6	15	16	20
850	215.0	6.4	4	10	5	12.5	16	20
851	216.0	6.4	5	12.5	6.0	15	14.5	18.13
852	216.0	6.2	5	12.5	6	15	16	20
853	216.0	6.5	3	7.5	5	12.5	16	20
854	217.0	6.3	4	10	6	15	16	20
855	217.0	6.6	3	7.5	5	12.5	16	20
856	218.0	6.4	4	10	6	15	16	20
857	218.0	6.7	2	5	5	12.5	16	20
858	219.0	6.5	3	7.5	6	15	16	20
859	219.0	6.8	1	2.5	6.0	15	16	20
860	220.0	6.6	3	7.5	6	15	16	20

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
861	220.0	6.9	1	2.5	6.0	15	16	20
862	221.0	6.7	2	5	6	15	16	20
863	221.0	7	0	0	6.0	15	16	20
864	222.0	6.4	5	12.5	6.0	15	14.5	18.13
865	222.0	6.8	1	2.5	6	15	16	20
866	222.0	5.8	7	17.5	6.0	15	16	20
867	223.0	6.9	1	2.5	6	15	16	20
868	223.0	5.9	6	15	6.0	15	16	20
869	224.0	6.4	5	12.5	6.0	15	14.5	18.13
870	224.0	7	0	0	6	15	16	20
871	224.0	6	6	15	6.0	15	16	20
872	225	6.3	6	15	5	12.5	17	21.25
873	225.0	5.8	7	17.5	6	15	16	20
874	225.0	6.1	5	12.5	6.0	15	16	20
875	226.0	5.9	6	15	6	15	17	21.25
876	226.0	6.2	5	12.5	7.0	17.5	17	21.25
877	227.0	6	6	15	6	15	17	21.25
878	227.0	6.3	4	10	7.0	17.5	17	21.25
879	228.0	6.1	5	12.5	6	15	17	21.25
880	228.0	6.4	4	10	7.0	17.5	17	21.25
881	229.0	6.2	5	12.5	6	15	17	21.25
882	229.0	6.5	3	7.5	7.0	17.5	17	21.25
883	230	6.2	4	10	5	12.5	14	17.5
884	230.0	6.3	4	10	6	15	17	21.25
885	230.0	6.6	3	7.5	7.0	17.5	17	21.25
886	231.0	6.4	4	10	6	15	17	21.25
887	231.0	6.7	2	5	7.0	17.5	17	21.25
888	232.0	6.5	3	7.5	6	15	17	21.25
889	232.0	6.8	1	2.5	7.0	17.5	17	21.25
890	233.0	6.6	3	7.5	6	15	17	21.25
891	233.0	6.9	1	2.5	7.0	17.5	17	21.25
892	234.0	6.3	5	12.5	5	12.5	15	18.75
893	234.0	6.7	2	5	5	12.5	17	21.25
894	234.0	7	0	0	7.0	17.5	17	21.25
895	235.0	6.8	1	2.5	5	12.5	17	21.25
896	235.0	5.8	7	17.5	7.0	17.5	17	21.25
897	236.0	6.9	1	2.5	5	12.5	17	21.25
898	236.0	5.9	6	15	7.0	17.5	17	21.25
899	237.0	7	0	0	5	12.5	17	21.25
900	237.0	6	6	15	7.0	17.5	17	21.25
901	238.0	5.8	7	17.5	6	15	17	21.25
902	238.0	6.1	5	12.5	7.0	17.5	17	21.25
903	239.0	5.9	6	15	6	15	17	21.25

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
904	239.0	6.2	5	12.5	7.0	17.5	17	21.25
905	240.0	6	6	15	6	15	17	21.25
906	240.0	6.3	4	10	7.0	17.5	17	21.25
907	241.0	6.1	5	12.5	6	15	17	21.25
908	241.0	6.4	4	10	7.0	17.5	17	21.25
909	242.0	6.2	5	12.5	6	15	17	21.25
910	242.0	6.5	3	7.5	7.0	17.5	17	21.25
911	243.0	6.3	4	10	6	15	17	21.25
912	243.0	6.6	3	7.5	5	12.5	17	21.25
913	244.0	6.4	4	10	6	15	17	21.25
914	244.0	6.7	2	5	5	12.5	17	21.25
915	245.0	6.5	3	7.5	6	15	17	21.25
916	245.0	6.8	1	2.5	5	12.5	17	21.25
917	246.0	6.6	3	7.5	6	15	17	21.25
918	246.0	6.9	1	2.5	5	12.5	17	21.25
919	247.0	6.7	2	5	6	15	17	21.25
920	247.0	7	0	0	5	12.5	17	21.25
921	248.0	6.8	1	2.5	6	15	18	22.5
922	248.0	5.8	7	17.5	5	12.5	18	22.5
923	249.0	6.9	1	2.5	6	15	18	22.5
924	249.0	5.9	6	15	5	12.5	18	22.5
925	250.0	7	0	0	6	15	18	22.5
926	250.0	6	6	15	5	12.5	18	22.5
927	251.0	6.2	5	12.5	5	12.5	15	18.75
928	251.0	5.8	7	17.5	6	15	18	22.5
929	251.0	6.1	5	12.5	5	12.5	18	22.5
930	252.0	5.9	6	15	6	15	18	22.5
931	252.0	6.2	5	12.5	5	12.5	18	22.5
932	253.0	6	6	15	6	15	18	22.5
933	253.0	6.3	4	10	5	12.5	18	22.5
934	254.0	6.1	5	12.5	6	15	18	22.5
935	254.0	6.4	4	10	5	12.5	18	22.5
936	255.0	6.4	5	12.5	5	12.5	15	18.75
937	255.0	6.2	5	12.5	6	15	18	22.5
938	255.0	6.5	3	7.5	5	12.5	18	22.5
939	256.0	6.3	4	10	6	15	18	22.5
940	256.0	6.6	3	7.5	5	12.5	18	22.5
941	257.0	6.4	4	10	6	15	18	22.5
942	257.0	6.7	2	5	5	12.5	18	22.5
943	258.0	6.4	5	12.5	5	18	15	18.75
944	258.0	6.5	3	7.5	6	15	18	22.5
945	258.0	6.8	1	2.5	5	12.5	18	22.5
946	259.0	6.6	3	7.5	6	15	18	22.5

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
947	259.0	6.9	1	2.5	5	12.5	18	22.5
948	260.0	6.7	2	5	5	12.5	18	22.5
949	260.0	7	0	0	5	12.5	18	22.5
950	261.0	6.8	1	2.5	5	12.5	18	22.5
951	261.0	5.8	7	17.5	5	12.5	18	22.5
952	262.0	6.9	1	2.5	5	12.5	18	22.5
953	262.0	5.9	6	15	5	12.5	18	22.5
954	263.0	7	0	0	0	0	18	22.5
955	263.0	6	6	15	5	12.5	18	22.5
956	264.0	5.8	7	17.5	7	17.5	18	22.5
957	264.0	6.1	5	12.5	5	12.5	18	22.5
958	265.0	5.9	6	15	7	17.5	18	22.5
959	265.0	6.2	5	12.5	5	12.5	18	22.5
960	266.0	6	6	15	7	17.5	18	22.5
961	266.0	6.3	4	10	5	12.5	18	22.5
962	267.0	6.1	5	12.5	6	15	18	22.5
963	267.0	6.4	4	10	5	12.5	18	22.5
964	268.0	6.2	5	12.5	7	17.5	18	22.5
965	268.0	6.5	3	7.5	5	12.5	18	22.5
966	269.0	6.3	4	10	6	15	18	22.5
967	269.0	6.6	3	7.5	5	12.5	18	22.5
968	270.0	6.4	4	10	5	12.5	18	22.5
969	270.0	6.7	2	5	5	12.5	18	22.5
970	271.0	6.5	3	7.5	5	12.5	19	23.75
971	271.0	6.8	1	2.5	5	12.5	19	23.75
972	272.0	6.6	3	7.5	5	12.5	19	23.75
973	272.0	6.9	1	2.5	5	12.5	19	23.75
974	273.0	6.7	2	5	5	12.5	19	23.75
975	273.0	7	0	0	5	12.5	19	23.75
976	274.0	6.8	1	2.5	5	12.5	19	23.75
977	274.0	5.8	7	17.5	6	15	19	23.75
978	275.0	6.9	1	2.5	5	12.5	19	23.75
979	275.0	5.9	6	15	6	15	19	23.75
980	276.0	7	0	0	5	12.5	19	23.75
981	276.0	6	6	15	6	15	19	23.75
982	277.0	5.8	7	17.5	6	15	19	23.75
983	277.0	6.1	5	12.5	6	15	19	23.75
984	278.0	5.9	6	15	6	15	19	23.75
985	278.0	6.2	5	12.5	5	12.5	19	23.75
986	279.0	6	6	15	5	12.5	19	23.75
987	279.0	6.3	4	10	5	12.5	19	23.75
988	280.0	6.1	5	12.5	5	12.5	19	23.75
989	281.0	6.2	5	12.5	5	12.5	19	23.75

Sample No	Turbidity	pH	Pre Lime (ppm)	Pre Lime (l/min)	Post Lime (ppm)	Post Lime (l/min)	Alum (ppm)	Alum (l/min)
990	282.0	6.3	4	10	5	12.5	19	23.75
991	283.0	6.4	4	10	5	12.5	19	23.75
992	284.0	6.5	3	7.5	5	12.5	19	23.75
993	285.0	6.6	3	7.5	5	12.5	19	23.75
994	286.0	6.7	2	5	5	12.5	19	23.75
995	287.0	6.8	1	2.5	5	12.5	19	23.75
996	288.0	6.9	1	2.5	5	12.5	19	23.75
997	289.0	7	0	0	5	12.5	19	23.75
998	290.0	5.8	7	17.5	5	12.5	19	23.75
999	291.0	5.9	6	15	5	12.5	19	23.75
1000	292.0	6	6	15	5	12.5	19	23.75

Note: All Turbidity values are in NTU.

Appendix-B

Tdty	pH	Lime (l/min)	Alum (l/min)	Quality of Water																				
				Settled Water												Filtered Water		Final Water						
				Pulsator		Pul tube		Cflock-1		Cflock-2		PT1		PT2				SPH			Kubota		
				Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Rcl	Tdty	pH	Rcl
14.8	6.6	7.5	11.02																				
24.2	6.6	7.5	11.34	1.3	6.2	2.2	6.2	2.0	6.2	1.6	6.2	2.0	6.2	1.9	6.2	0.8	6.4	0.5	7.3	1.1	0.9	7.2	1.1
23.4	6.6	7.5	11.31																				
24.2	6.6	7.5	11.34	1.1	6.4	2.0	6.4	1.9	6.2	2.2	6.2	1.8	6.2	2.1	6.2	0.8	6.4	0.4	7.1	1.0	0.8	7.2	1.0
24.8	6.6	7.5	11.36																				
25.4	6.6	7.5	11.38	1.3	6.4	1.8	6.4	2.2	6.4	2.4	6.4	1.8	6.4	1.8	6.4	0.7	6.4	0.4	7.1	1.1	0.9	7.7	0.8
25.7	6.6	7.5	11.39																				
23.5	6.65	7.5	11.31	1.3	6.4	1.9	6.4	2.3	6.2	2.6	6.2	1.8	6.4	1.7	6.4	0.7	6.4	0.3	7.0	1.1	1.0	7.5	1.0
23.6	6.65	7.5	11.32																				
23.7	6.65	7.5	11.32	1.05	6.4	1.1	6.4	2.0	6.2	2.4	6.2	1.7	6.2	1.6	6.2	0.7	6.4	0.4	7.4	0.8	0.9	7.3	1.1
23.7	6.6	7.5	11.32																				
23.6	6.6	7.5	11.32	1.4	6.4	1.2	6.4	1.9	6.2	2.2	6.2	1.8	6.4	1.4	6.4	0.7	6.4	0.4	7.1	1.0	1.1	7.2	0.9
23.6	6.7	5	11.32																				
23.7	6.7	5	11.32	1.09	6.2	3.7	6.2	1.7	6.2	1.9	6.2	3.2	6.2	3.2	6.2								
23.9	6.7	5	11.33													0.4	6.2	0.5	7.1	1.0	0.7	6.9	1.0
24.2	6.7	5	11.34	1	6.2	3.9	6.2	1.7	6.2	1.8	6.2	3.4	6.2	2.9	6.2								
24.6	6.7	5	11.35																				
28.1	6.7	5	11.47	0.98	6.2	2.9	6.2	1.7	6.2	1.7	6.2	3.6	6.2	2.5	6.2	0.4	6.2	0.5	7.2	0.9	0.7	7.0	1.1
28.3	6.7	5	11.48																				
29.6	6.7	5	11.52	1.12	6.2	3.3	6.2	1.8	6.2	1.8	6.2	3.3	6.2	2.7	6.2								
27.1	6.7	5	11.43													0.4	6.2	0.5	7.3	4.0	0.7	6.9	1.0
25.9	6.7	5	11.39	1.47	6.8	3.1	6.8	1.9	6.3	1.5	6.3	3.4	6.3	2.8	6.3								
24.2	6.7	5	11.34																				
23.9	6.7	5	11.33	1.56	6.4	3.2	6.4	2.1	6.4	1.4	6.4	3.4	6.4	3.0	6.4	0.4	6.4	0.4	7.4	1.1	0.8	7.0	1.0
59.6	6.6	7.5	12.61																				
55.4	6.5	7.5	12.45	2.3	6.6	3.8	6.4	4.7	6.6	4.8	6.6	4.9	6.5	4.9	6.5								
55.0	6.6	7.5	12.44													1.1	6.6	1.0	7.6	1.0	0.9	7.3	1.0
54.2	6.6	7.5	12.41	1.78	6.6	4.0	6.5	5.1	6.6	4.5	6.6	4.2	6.5	4.6	6.5								
52.4	6.6	7.5	12.34																				
52.1	6.6	7.5	12.33	1.49	6.6	4.2	6.4	5.7	6.6	4.3	6.6	3.7	6.5	4.6	6.5	1.1	6.6	1.0	7.6	1.0	0.9	7.3	1.0
54.3	6.6	7.5	12.41																				
76.4	6.6	7.5	13.27	1.73	6.6	4.3	6.4	2.1	6.5	2.2	6.5	2.1	6.5	2.8	6.5	1.2	6.6	1.0	7.6	1.0	1.0	7.3	1.0

Tdty	pH	Lime (l/min)	Alum (l/min)	Quality of Water																					
				Settled Water												Filtered Water		Final Water					
				Pulsator		Pul.tube		Cflock-1		Cflock-2		PT1		PT2				SPH			Kubota		
				Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Rcl	Tdty	pH	Rcl
156.0	6.5	7.5	16.85	2.32	6.4	4.9	6.4	2.7	6.5	2 4	6.5	2.9	6.5	3.6	6.5	1.4	6.6	1.2	8.0	1.0	1.1	7.2	1.0
133.0	6.5	7.5	15.73																				
124.0	6.5	7.5	15.32	2.8	6.4	5.1	6.4	2.7	6.5	2.4	6.5	4.1	6.6	4.6	6.6	1.3	6.6	0.4	7.1	1.0	1.4	7.0	1.0
131.0	6.5	7.5	15.64																				
130.0	6.5	7.5	15.59	1.84	6.4	4.0	6.5	3.1	6.7	3.2	6.6	4.3	6.6	4.6	6.6	1.3	6.6	0.5	7.3	1.0	1.3	7.0	1.0
114.0	6.5	7.5	14.86																				
108.0	6.5	7.5	14.60	1.61	6.4	3.8	6.5	3.9	6.5	3.8	6.6	4.6	6.6	4.9	6.6	1.4	6.6	0.7	7.4	1.0	1.3	7.0	1.0
93.4	6.5	7.5	13.97																				
86.4	6.5	7.5	13.68	1.57	6.4	3.8	6.4	4.1	6.5	3.4	6.6	4.6	6.6	4.8	6.6	1.2	6.6	0.7	7.4	1.0	1.1	7.0	1.0
79.2	6.5	7.5	13.38																				
76.1	6.5	7.5	13.26	1.53	6.4	3.7	6.4	4.7	6.5	3.2	6.6	4.7	6.6	5.1	6.6	1.3	6.6	0.7	7.4	1.0	1.2	7.0	1.0
66.4	6.5	7.5	12.87																				
65.1	6.6	7.5	12.82	1.74	6.0	2.6	6.0	5.2	6.0	3.8	6.0	5.9	6.0	4.9	6.0	1.3	6.0	1.0	7.4	0.9	1.2	7.2	1.1
66.1	6.6	7.5	12.86																				
89.0	6.6	7.5	13.78																				
159.0	6.6	7.5	17.00	1.4	6.4	1.1	6.4	2.7	6.4	5.3	6.4	3.8	6.4	3.9	6.5	0.8	6.5	1.0	7.5	1.0	0.6	7.3	1.0
204.0	6.4	10	19.37																				
222.0	6.4	10	20.39													0.8	6.4	0.8	7.4	1.0	0.6	7.3	1.0
224.0	6.4	10	20.50	1.7	6.4	1.1	6.4	3.7	6.4	7.8	6.4	3.6	6.5	3.9	6.5	6.4	0.1	1.0	7.4	1.0	0.6	7.4	1.0
216.0	6.4	10	20.05																				
200.0	6.2	12.5	19.15	4.3	5.9	3.4	6.0	6.9	5.9	10.3	5.9	6.1	6.0	7.2	6.0								
191.0	6.2	12.5	18.66																				
182.0	6.2	12.5	18.18	4.0	6.2	3.1	6.2	5.0	6.2	9.1	6.2	5.8	6.2	6.3	6.2			4.6	7.4	0.9	2.6	7.4	1.1
169.0	6.1	12.5	17.50																				
155.0	6.2	12.5	16.80	3.1	6.2	3.6	6.2	5.0	6.2	8.9	6.2	5.3	6.2	5.9	6.2	1.1	6.2	1.8	7.8	0.9	1.3	7.2	1.2
139.0	6.2	12.5	16.02																				
124.0	6.2	12.5	15.32	3.1	6.2	3.8	6.2	4.0	6.2	6.2	6.2	4.9	6.2	5.5	6.2								
109.0	6.2	12.5	14.64																				
95.0	6.2	12.5	14.04	2.9	6.2	3.4	6.2	3.1	6.2	5.4	6.2	4.2	6.2	4.4	6.2	1.2	6.2	1.4	8.2	0.9	1.8	7.8	1.1
86.0	6.3	10	13.66																				
73.0	6.3	10	13.13	3.2	6.2	3.7	6.2	2.9	6.2	6.4	6.2	4.8	6.2	4.8	6.2	1.2	6.2	1.4	8.1	6.9	1.4	8.1	1.0
67.0	6.3	10	12.90																				
64.0	6.3	10	12.78	3.0	6.2	3.5	6.2	2.8	6.2	6.8	6.2	4.3	6.2	4.1	6.2	1.1	6.2	1.2	7.5	0.9	1.1	7.9	1.1

Tdty	pH	Lime (l/min)	Alum (l/min)	Quality of Water																			
				Settled Water												Filtered Water		Final Water					
				Pulsator		Pul.tube		Cflock-1		Cflock-2		PT1		PT2				SPH			Kubota		
				Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Rcl	Tdty	pH	Rcl
60.0	6.4	10	12.63	2.8	6.4	3.4	6.4	3.8	6.4	4.4	6.4	4.4	6.4	4.6	6.4	1.1	6.4	1.2	7.4	0.9	0.7	7.2	1.1
7.6	6.8	5	10.79	1.0	6.5	0.6	6.5	3.7	6.6	1.5	6.6	1.7	6.6	1.9	6.6	1.2	6.7	2.1	6.9	0.8	0.8	7.1	0.8
7.6	6.8	5	10.79																				
7.7	6.8	5	10.79	0.7	6.5	0.9	6.5	1.2	6.5	0.9	6.6	1.0	6.5	1.4	6.5	1.1	6.7	1.4	7.3	0.9	0.8	7.5	0.9
7.7	6.8	5	10.79																				
7.7	6.8	5	10.79	0.7	6.5	0.9	6.5	1.6	6.5	0.9	6.6	1.6	6.5	1.4	6.5	1.0	6.7	0.8	7.9	0.9	0.8	8.0	0.9
7.6	6.9	2.5	10.79																				
7.5	6.9	2.5	10.79	0.8	6.5	1.08	6.5	1.8	6.5	1.2	6.6	1.8	6.5	2.2	6.5	1.0	6.7	0.9	7.9	0.9	0.8	8.0	0.9
7.3	6.9	2.5	10.78																				
7.3	6.9	2.5	10.78	0.8	6.5	1.5	6.5	1.8	6.3	1.2	6.6	2.4	6.5	2.7	6.5	0.9	0.7	0.7	7.6	0.9	0.8	7.8	0.9
7.3	6.9	2.5	10.78																				
7.4	6.9	2.5	10.78																				
7.5	6.9	2.5	10.79	0.8	6.5	1.5	6.5	1.1	6.5	1.1	6.6	2.2	6.5	2.5	6.5								
7.5	6.9	2.5	10.79													0.9	6.7	0.7	7.8	0.9	0.7	7.4	0.9
7.5	6.9	2.5	10.79																				
7.4	6.9	2.5	10.78	0.8	6.5	1.6	6.5	1.0	6.5	1.0	6.6	2.1	6.5	2.3	6.5	0.8	6.7	0.7	7.8	0.9	0.7	7.4	0.9
7.3	6.9	2.5	10.78																				
7.2	6.9	2.5	10.78	0.8	6.5	1.4	6.5	0.9	6.5	1.0	6.6	1.9	6.5	2.1	6.8	0.8	6.7	0.7	7.8	0.9	0.6	7.3	0.9
13.2	6.5	7.5	10.97																				
13.9	6.6	7.5	10.99	1.6	6.4	1.9	6.4	1.6	6.4	1.6	6.4	1.5	6.4	2.4	6.4								
15.1	6.6	7.5	11.03															0.6	7.8	0.9	0.4	7.7	1.1
24.3	6.7	5	11.34																				
41.9	6.7	5	11.95																				
57.3	6.8	5	12.52															0.5	8.0	0.8	0.5	7.7	1.2
87.9	6.8	5	13.74																				
125.0	6.7	5	15.36																				
179.0	6.6	7.5	18.02															0.7	8.1	0.8	0.5	7.7	1.0
214.0	6.5	7.5	19.93																				
255.0	6.4	10	22.36																				
258.0	6.4	10	22.54															0.5	8.0	0.80.89		7.6	0.8
251.0	6.2	12.5	22.11																				
234.0	6.3	10	21.09																				
195.0	6.4	10	18.88															1.0	8.0	0.9	1.3	7.9	1.1

				Quality of Water																			
				Settled Water												Filtered Water		Final Water					
		Lime	Alum	Pulsator		Pul.tube		Cflock-1		Cflock-2		PT1		PT2				SPH			Kubota		
Tdty	pH	(l/min)	(l/min)	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Tdty	pH	Rcl	Tdty	pH	Rcl
132.0	6.4	10	15.69																				
129.0	6.4	10	15.55																				
126.0	6.4	10	15.41																				
120.0	6.4	10	15.13																				
98.0	6.4	10	14.16																				
94.0	6.4	10	13.99																				
43.0	6.5	7.5	11.99																				
40.1	6.5	7.5	11.89	1.3	6.2	2.2	6.2	2.0	6.2	1.6	6.2	2.0	6.2	1.9	6.2	0.8	6.4	0.8	7.3	1.1	0.9	7.2	1.1
38.5	6.5	7.5	11.83																				
37.4	6.5	7.5	11.79	1.1	6.4	2.0	6.4	1.9	6.2	2.2	6.2	1.8	6.2	2.1	6.2	0.8	6.4	0.8	7.1	1.0	0.8	7.2	1.0
35.5	6.5	7.5	11.73																				
41.2	6.5	7.5	11.93	1.3	6.4	1.8	6.4	2.2	6.4	2.4	6.4	1.8	6.4	1.8	6.4	0.7	6.4	0.8	7.1	1.1	0.9	7.7	0.8
41.4	6.5	7.5	11.94																				
49.3	6.5	7.5	12.22	1.3	6.4	1.9	6.4	2.3	6.2	2.6	6.2	1.8	6.4	1.7	6.4	0.7	6.4						
57.0	6.5	7.5	12.51															0.9					
123.0	6.5	7.5	15.27	1.05	6.4	1.1	6.4	2.0	6.2	2.4	6.2	1.7	6.2	1.6	6.2	0.7	6.4						
139.0	6.5	7.5	16.02																				
168.0	6.5	7.5	17.45	1.4	6.4	1.2	6.4	1.9	6.2	2.2	6.2	1.8	6.4	1.4	6.4	0.7	6.4	0.9	7.1	1.0	1.1	7.2	0.9
142.0	6.5	7.5	16.16																				
128.0	6.5	7.5	15.50	1.09	6.2	3.7	6.2	1.7	6.2	1.9	6.2	3.2	6.2	3.2	6.2								
118.0	6.5	7.5	15.04													0.4	6.2	0.9	7.1	1.0	0.7	6.9	1.0
115.0	6.5	7.5	14.91	1	6.2	3.9	6.2	1.7	6.2	1.8	6.2	3.4	6.2	2.9	6.2								
112.0	6.5	7.5	14.77																				
105.0	6.5	7.5	14.47	0.98	6.2	2.9	6.2	1.7	6.2	1.7	6.2	3.6	6.2	2.5	6.2	0.4	6.2	0.9	7.2	0.9	0.7	7.0	1.1
101.0	6.5	7.5	14.29																				
45.8	6.5	7.5	12.10	1.12	6.2	3.3	6.2	1.8	6.2	1.8	6.2	3.3	6.2	2.7	6.2								
91.3	6.5	7.5	13.88													0.4	6.2	0.9	7.3	4.0	0.7	6.9	1.0
85.7	6.5	7.5	13.65	1.47	6.8	3.1	6.8	1.9	6.3	1.5	6.3	3.4	6.3	2.8	6.3								
80.2	6.5	7.5	13.42																				
77.0	6.5	7.5	13.29	1.56	6.4	3.2	6.4	2.1	6.4	1.4	6.4	3.4	6.4	3.0	6.4	0.4	6.4	1.0	7.4	1.1	0.8	7.0	1.0

Appendix-C

Setting up Peripherals

Before writing the setting up code for the devices, all the constants that have to be used in the source code have been defined. Apart from that a set of variables are defined to make it easier to access memory locations.

```
#define     up          2
#define     down        1
count       0×21
packet      0×22
temp        0×23
digit1      0×24
digit2      0×25
digit3      0×26
digit4      0×27
digit5      0×28
digit6      0×29
digit7      0×2A
digit8      0×2B

Status_temp     equ     0×2C
t1              equ     0×2D
t2              equ     0×2E
t3              equ     0×2F
L_byte          equ     0×30
H_byte          equ     0×31
R0              equ     0×32
R1              equ     0×33
R2              equ     0×34
t4              equ     0×35
t5              equ     0×36
t6              equ     0×37
minimum         equ     0×38
maximum         equ     0×39
counter         equ     0×3A
cur_turbidity   equ     0×3B
set_turbidity   equ     0×3C
w_turbidity     equ     0×3D
```

```
time                equ     0×3E
pclath_turbidity    equ     0×3F
flag                equ     0×40

send_spi            macroaddress, no            ;macro for SPIsending
movlw               address
call                data_send
movlw               no
call                data_send
endm
```

The include file PIC16F876.inc is included to let the MPLAB compiler to understand which device of the family is being used.

```
include     "PIC16F876.inc"

_config _cp_off&_WDT_OFF&_BODEN_off&_PWRTE_off&_XT_osc

list
```


At the beginning of the device the port and variable initialization step starts. The following code fragment depicts what are the registers that have to be initialized in this manner. Reset vector and Interrupt vector originating locations are mentioned with two 'goto' lables.

```
org 0×000
goto        start
org 0×004

start               ;timer1 interrupts used with internal  oscillator, MAX7219 display

banksel     TRISC
movlw       b'00000011'
movwf       TRISC
movlw       0×FF
movwf       TRISB
clrf        TRISA
bsf         TRISA,1
banksel     OPTION_REG
```

```
clrf     OPTION_REG
bsf      OPTION_REG,7
bsf      PIE1,0
banksel  PORTC
clrf     PORTC
clrf     PORTA
clrf     PORTB
clrf     ADCON0
movlw    0×0D
movlw    T1CON
clrf     flag
clrf     TMR1H
clrf     TMR1H
clrf     TMR1L
movlw    0×02
movwf    time

movlw    0×C0
movwf    INTCON
clrf     PIR1
movlw    0×0F
movwf    digit1
movwf    digit2
movwf    digit3
movwf    digit4
movwf    digit5
movwf    digit6
movwf    digit7
movwf    digit8

Initialize

banksel  ADCON0          ;RA1 input is the Analog input proportional to
turbidity
movlw    0×49
movwf    ADCON0
clrf     PIR1
banksel  ADCON1
movlw    0×84
movwf    ADCON1
```

```
clrf       ADRESL
banksel    ADRESH
clrf       ADRESH
clrf       H_byte
clrf       L_byte

SPI

banksel    SSPSTAT
clrf       SSPSTAT
banksel    SSPCON
movlw      0×30
movwf      SSPCON
movlw      0×02
movwf      packet


Start
banksel    PORTB
clrf       PORTB                    ; clear PORTB
movlw      B'01000001'              ; Fosc/8, A/D enabled
banksel    OPTION_REG
movlw      B'10000111'              ; TMR0 prescaler, 1:256 (20µs)
movwf      OPTION_REG
movwf      ADCON0
clrf       TRISB                    ; PORTB all outputs
movlw      B'00001110'              ; Left justify, 1 analog channel
movwf      ADCON1                   ; VDD and VSS references
banksel    PORTB

Main
        btfss      INTCON,T0IF      ; Wait for Timer0 to timeout
        goto       Main
        bcf        INTCON,T0IF
        bsf        ADCON0,GO        ; Start A/D conversion
Wait
        btfss      PIR1,ADIF        ; Wait for conversion to complete
        goto       Wait
        movf       ADRESH,W         ; Write A/D result to PORTB
        movwf      PORTB
```

```
        clrf      PORTB

send_tur                          ; sends current turbidity to the display
        movelw    0×0F
        andwf     R2,w
        movwf     digit1
        swapf     R2,f
        movlw     0×0F
        andwf     R2,w
        movwf     digit2
        movlw     0×0F
        andwf     R1,w
        movwf     digit3

        movlw     0×FF
        andwf     digit3,1
        btfss     STATUS,2
        goto      test_tur1
        movlw     0×0F
        movwf     digit3
test_tur1
        movlw     0×FF
        andwf     digit2,1
        btfss     STATUS,2
        goto      send_tur1
test_tur2
        movelw    0×0F
        xorwf     digit3,0
        btfss     STATUS,2
        goto      send_tur1
        movlw     0×0F
        movwf     digit2
send_tur1
        movlw     0×04
        call      data_send
        movf      digit4,0                 ; dig1 data
        call      data_send
        movlw     0×03
        call      data_send
```

```
            movf        digit3,0                          ; dig2 data
            call        data_send
            movlw       0×02
            call        data_send
            movf        digit2,0                          ; dig3 data
            call        data_send
            movlw       0×01
            call        data_send
            movf        digit1,0                          ; dig1 data
            call        data_send
            return

send_initial                          ; sends initial turbidity to the display
            movelw      0×0F
            andwf       R2,w
            movwf       digit5
            swapf       R2,f
            movlw       0×0F
            andwf       R2,w
            movwf       digit6
            movlw       0×0F
            andwf       R1,w
            movwf       digit7

            movlw       0×FF
            andwf       digit7,1
            btfss       STATUS,2
            goto        test_initial1
            movlw       0×0F
            movwf       digit7
test_initial1
            movlw       0×FF
andwf                   digit6,1
            btfss       STATUS,2
            goto        send_initial1
test_initial2
            movelw      0×0F
            xorwf       digit7,0
            btfss       STATUS,2
            goto        send_initial1
```

```
        movlw       0x0F
        movwf       digit6
send_initial1
        movlw       0x08
        call        data_send
        movf        digit8,0                        ; dig1 data
        call        data_send
        movlw       0x07
        call        data_send
        movf        digit7,0                        ; dig2 data
        call        data_send
        movlw       0x06
        call        data_send
        movf        digit5,0                        ; dig3 data
        call        data_send
        movlw       0x05
        call        data_send
        movf        digit1,0                        ; dig1 data
call    data_send
        return

        ADC                                         ; Analog to digital conversion
                                                    and current turbidity update

        banksel     ADCON0
        bsf         ADCON0,2
        goto loop

loop
        btfss       PIR1,6
        goto        loop
        bcf         PIR1,6
        banksel     ADRESH
        movf        ADRESH,w
        movwf       H_byte
        rrf         H_byte,1
        banksel     ADRESL
        movf        ADRESL,w
        banksel     L_byte
        movwf       L_byte
```

```
            rrf       H_byte,1
            movlw     0×01
            andwf     H_byte,1
            movf      L_byte,0
            movwf     cur_tur

            return

compare                          ;routine used to compare current turbidity
                                 with initial turbidity
            movf      cur_tur,0
            subwf     ini-tur,0
            btfss     STATUS,1
            goto      ON
            goto      compare
end
```

Appendix-D

Turbidity (NTU)	Dossage (l/min)	Movement (°)	Turbidity (NTU)	Dossage (l/min)	Movement (°)
4	10.20	91.8	54	12.87	115.9
5	10.25	92.3	55	12.93	116.4
6	10.30	92.7	56	12.99	116.9
7	10.35	93.2	57	13.04	117.4
8	10.40	93.6	58	13.10	117.9
9	10.45	94.1	59	13.16	118.4
10	10.51	94.6	60	13.22	118.9
11	10.56	95.0	61	13.27	119.5
12	10.61	95.5	62	13.33	120.0
13	10.66	95.9	63	13.39	120.5
14	10.71	96.4	64	13.45	121.0
15	10.76	96.9	65	13.50	121.5
16	10.82	97.3	66	13.56	122.1
17	10.87	97.8	67	13.62	122.6
18	10.92	98.3	68	13.68	123.1
19	10.97	98.7	69	13.74	123.6
20	11.02	99.2	70	13.79	124.1
21	11.08	99.7	71	13.85	124.7
22	11.13	100.2	72	13.91	125.2
23	11.18	100.6	73	13.97	125.7
24	11.23	101.1	74	14.03	126.3
25	11.29	101.6	75	14.09	126.8
26	11.34	102.1	76	14.15	127.3
27	11.39	102.5	77	14.21	127.9
28	11.45	103.0	78	14.27	128.4
29	11.50	103.5	79	14.32	128.9
30	11.55	104.0	80	14.38	129.5
31	11.61	104.5	81	14.44	130.0
32	11.66	105.0	82	14.50	130.5
33	11.72	105.4	83	14.56	131.1
34	11.77	105.9	84	14.62	131.6
35	11.82	106.4	85	14.68	132.2
36	11.88	106.9	86	14.74	132.7
37	11.93	107.4	87	14.80	133.2
38	11.99	107.9	88	14.86	133.8
39	12.04	108.4	89	14.93	134.3
40	12.10	108.9	90	14.99	134.9
41	12.15	109.4	91	15.05	135.4
42	12.21	109.9	92	15.11	136.0
43	12.26	110.3	93	15.17	136.5
44	12.32	110.8	94	15.23	137.1
45	12.37	111.3	95	15.29	137.6
46	12.43	111.8	96	15.35	138.2
47	12.48	112.3	97	15.41	138.7
48	12.54	112.8	98	15.48	139.3
49	12.59	113.3	99	15.54	139.8
50	12.65	113.9	100	15.60	140.4
51	12.71	114.4	101	15.66	141.0
52	12.76	114.9	102	15.72	141.5
53	12.82	115.4	103	15.79	142.1

Turbidity (NTU)	Dossage (l/min)	Movement (°)	Turbidity (NTU)	Dossage (l/min)	Movement (°)
104	15.85	142.6	155	19.19	172.7
105	15.91	143.2	156	19.26	173.3
106	15.97	143.8	157	19.33	174.0
107	16.04	144.3	158	19.40	174.6
108	16.10	144.9	159	19.47	175.2
109	16.16	145.5	160	19.54	175.8
110	16.23	146.0	161	19.61	176.4
111	16.29	146.6	162	19.67	177.1
112	16.35	147.2	163	19.74	177.7
113	16.42	147.7	164	19.81	178.3
114	16.48	148.3	165	19.88	179.0
115	16.54	148.9	166	19.95	179.6
116	16.61	149.5	167	20.02	180.2
117	16.67	150.0	168	20.09	180.8
118	16.74	150.6	169	20.16	181.5
119	16.80	151.2	170	20.23	182.1
120	16.86	151.8	171	20.30	182.7
121	16.93	152.4	172	20.38	183.4
122	16.99	152.9	173	20.45	184.0
123	17.06	153.5	174	20.52	184.6
124	17.12	154.1	175	20.59	185.3
125	17.19	154.7	176	20.66	185.9
126	17.25	155.3	177	20.73	186.6
127	17.32	155.9	178	20.80	187.2
128	17.38	156.4	179	20.87	187.9
129	17.45	157.0	180	20.94	188.5
130	17.51	157.6	181	21.02	189.1
131	17.58	158.2	182	21.09	189.8
132	17.65	158.8	183	21.16	190.4
133	17.71	159.4	184	21.23	191.1
134	17.78	160.0	185	21.30	191.7
135	17.84	160.6	186	21.38	192.4
136	17.91	161.2	187	21.45	193.0
137	17.98	161.8	188	21.52	193.7
138	18.04	162.4	189	21.59	194.3
139	18.11	163.0	190	21.67	195.0
140	18.18	163,6	191	21.74	195.6
141	18.24	164.2	192	21.81	196.3
142	18.31	164.8	193	21.88	197.0
143	18.38	165.4	194	21.96	197.6
144	18.44	166.0	195	22.03	198.3
145	18.51	166.6	196	22.10	198.9
146	18.58	167.2	197	22.18	199.6
147	18.65	167.8	198	22.25	200.3
148	18.71	168.4	199	22.33	200.9
149	18.78	169.0	200	22.40	201.6
150	18.85	169.7	201	22.47	202.3
151	18.92	170.3	202	22.55	202.9
152	18.99	170.9	203	22.62	203.6
153	19.05	171.5	204	22.70	204.3
154	19.12	172.1	205	22.77	204.9

Turbidity (NTU)	Dossage (l/min)	Movement (°)	Turbidity (NTU)	Dossage (l/min)	Movement (°)
206	22.85	205.6	253	26.49	238.4
207	22.92	206.3	254	26.57	239.1
208	23.00	207.0	255	26.65	239.9
209	23.07	207.6	256	26.73	240.6
210	23.15	208.3	257	26.81	241.3
211	23.22	209.0	258	26.89	242.0
212	23.30	209.7	259	26.97	242.8
213	23.37	210.3	260	27.06	243.5
214	23.45	211.0	261	27.14	244.2
215	23.52	211.7	262	27.22	245.0
216	23.60	212.4	263	27.30	245.7
217	23.68	213.1	264	27.38	246.4
218	23.75	213.8	265	27.46	247.2
219	23.83	214.4	266	27.55	247.9
220	23.90	215.1	267	27.63	248.6
221	23.98	215.8	268	27.71	249.4
222	24.06	216.5	269	27.79	250.1
223	24.13	217.2	270	27.87	250.9
224	24.21	217.9	271	27.96	251.6
225	24.29	218.6	272	28.04	252.4
226	24.36	219.3	273	28.12	253.1
227	24.44	220.0	274	28.20	253.8
228	24.52	220.7	275	28.29	254.6
229	24.60	221.4	276	28.37	255.3
230	24.67	222.1	277	28.45	256.1
231	24.75	222.8	278	28.54	256.8
232	24.83	223.5	279	28.62	257.6
233	24.91	224.2	280	28.70	258.3
234	24.99	224.9	281	28.79	259.1
235	25.06	225.6	282	28.87	259.8
236	25.14	226.3	283	28.96	260.6
237	25.22	227.0	284	29.04	261.4
238	25.30	227.7	285	29.12	262.1
239	25.38	228.4	286	29.21	262.9
240	25.46	229.1	287	29.29	263.6
241	25.53	229.8	288	29.38	264.4
242	25.61	230.5	289	29.46	265.2
243	25.69	231.2	290	29.55	265.9
244	25.77	231.9	291	29.63	266.7
245	25.85	232.7	292	29.72	267.4
246	25.93	233.4	293	29.80	268.2
247	26.01	234.1	294	29.89	269.0
248	26.09	234.8	295	29.97	269.7
249	26.17	235.5	296	30.06	270.5
250	26.25	236.3	297	30.14	271.3
251	26.33	237.0	298	30.23	272.1
252	26.41	237.7	299	30.31	272.8