Chapter 1

INTRODUCTION

With increasing heat as summertime comes, swimming pool resorts especially public ones are one of the in-demand places most people go to refresh and enjoy their summer vacation. Due to that increased demand, pool monitoring will be more challenging to maintenance personnel. Public swimming pools, when left untreated, will result to a muddy, dark, and foul-smelling water which is hazardous to swimmers. The overuse of chlorine may result to a decrease in potential of hydrogen (pH) level which may result to skin and eye irritations as well as pool equipment corrosion such as rusting of mounting brackets and hand rails. Despite the presence of rust, it will not directly affect a person’s health because tetanus spores are eliminated by chlorine and these spores are incapable of surviving in water. However, rust can still cause detrimental effects such as stains on pool and damage on water pumps. In contrast, insufficient chlorine can result to formation of phytoplankton (pool algae) which may lead to formation of hazardous bacteria such as Escherichia coli O157:H7 which is part cryptosporidium germ that causes diarrheal illness.

One of the most frequently used test method in analyzing the water’s chlorine level is with the use of color comparator which visually match the reacted sample of water with series of color standards or reference chart to determine the concentration level of the chlorine from the sample. Another method used is the application of the residual chlorine and pH meter which gives the digital measurement of the chlorine and pH level. However, this may be efficient but is quite expensive and also lacks data parameter interpretation. In a study by Amici Water Systems, Philippines it was determined that pH level above 8.0 will cause pool wall discoloration and inefficient chlorine disinfection.

Currently, the analysis of water samples is done in laboratories using advanced systems that requires trained personnel. Also, other pool water monitoring devices lack data interpretation and alert system. This is economically impractical due to complex equipment required in determining the chemical constituents of water for real-time monitoring. To address these problems, the researchers would be utilizing Raspberry Pi and various compatible sensors specifically for the pH and chlorine of the water. The device will display its interpretation of the gathered data in relation to possible adverse effects on health and pool equipment.

The main objective of the study is to devise a system that will monitor the swimming pool's ORP and pH level. Particularly, the researchers aim to (1) develop a microcontroller based prototype which utilizes pH and ORP sensors for data gathering of pH and ORP level (2) determine the accuracy of the prototype through laboratory testing of the parameters being tested (3) design an alert system to indicate the possible adverse effect of the pool water condition.

This study will be significant primarily to pool goers because the device will mainly monitor the ORP and pH level of the pool. Based on the amount of ORP and pH levels detected, the device will process the data and give its corresponding analysis on whether the water can possibly cause harmful health conditions. Secondly, this study will be beneficial to pool owners because they can prevent possible adverse effects on their pool equipment like corrosion and the formation of algae that causes stains and bacterial growth. Lastly, this study will be significant to future researchers since this research paper will serve as a reference for them.

The research focuses on monitoring swimming pool water specifically its pH and ORP levels. In addition, the device will utilize Raspberry Pi 3 to run the program that will interpret the data gathered by the pH and ORP sensors. Moreover, the device can only analyze that the pool is suitable for bacteria growth but it does not know the types of bacteria that is present in the water.

Furthermore, the device only knows the level of pH and ORP wherein corrosion will take place on the pool but not the amount of corroded metals present in the water. In the case of high level pH or inadequate chlorine, the device alerts the user via Bluetooth terminal and light indicator to address urgent water regulation at the pool. The device only suggests recommendations to prevent the adverse effect but does not surely eliminates the possibility of its occurrence.

Chapter 2

REVIEW OF RELATED LITERATURE

2.1 Factors affecting Pool Water quality

2.1.1 pH Level

The abbreviation pH is of French origin "puissance d'Hydrogène" [1], it is actually a measure of hydrogen ions in water scaled from 0-14. It is often used as inaccurate description of alkalinity or acidity of liquid. A pH level of seven is said to be neutral for pure water while less than 7 means acidic content and having a pH greater than 7 might suggests an increase in alkalinity [2]. For pool water maintenance it is advised to maintain a pH level 7.2-7.8 [3] to match the tolerable level for the eyes and mucus membrane while maintaining the level that will not result to corrosion of tiles and metals [4]. Another important reason for pH monitoring is that it is crucial in the production of hypochlorous acid that is the strong form of chlorine disinfectant. The pH value is inversely related to the HOCL, it was found out that 60 percent of HOCL exist at 7.2 pH level while 90 percent of it exists at 8.5pH level [2].

Inflatable pool which uses ground water will have a pH ranging from 6.8-8.5. The NSW Health released a table which suggest method to lower and increase pH of water with the use of sodium bicarbonate and sodium bisulphate. [6]

Pool volume (kL)	Dose of sodium bicarbonate ($NaHCO_3$) to raise pH to 7.5			
	Measured pH			
	5.5	6.0	6.5	7.0
10	0.5 kg	0.36 kg	0.24 kg	0.16 kg
20	1.0 kg	0.72 kg	0.48 kg	0.3 kg
30	1.5 kg	1.08 kg	0.72 kg	0.48 kg
50	2.4 kg	1.8 kg	1.2 kg	0.8 kg
100	7.0 kg	3.6 kg	2.4 kg	1.6 kg

Note: When using sodium carbonate (soda ash) to increase pH to 7.5, halve the quantity i.e. 2 kg sodium bicarbonate (dry alkali or pH buffer) = 1 kg sodium carbonate (soda ash)

Figure 2.1: This shows the dose of Sodium Bicarbonate needed to raise the pH to 7.5 [6]

Pool volume (kL)	Dose of dry acid (sodium bisulphate NaHSO4) to lower pH to 7.5			
	Measured pH			
	7.8	8.0	8.5	9.0
10	0.05 kg	0.11 kg	0.18 kg	0.26 kg
20	0.1 kg	0.22 kg	0.36 kg	0.52 kg
30	0.15 kg	0.33 kg	0.54 kg	0.78 kg
50	0.25 kg	0.55 kg	0.9 kg	1.3 kg
100	0.5 kg	1.1 kg	1.8 kg	2.6 kg

Figure 2.2: This shows the dose of Sodium Bisulphate needed to lower the pH to 7.5 [6]

2.1.2 Chlorine Level

In pool regulation chlorine is a loose term used for the many types of chlorine disinfectants, [5] it is the most commonly used chemical for water disinfection because it has the ability to inactivate most disease-causing germs in water. The ability of chlorine to disinfect is dependent on its concentration. To provide the necessary disinfection, Oxidation reduction Potential (ORP) must be greater than 720 mV.[6]

2.2 Statistics of pool water related disease outbreak

2.2.1 Local

The Department of Health never fail to alert the public on the possible disease that can be acquired on poorly-maintained or unmaintained swimming pools. DOH reminds pool-goers of sore eyes, skin disease, and stomach related inflammation which are prevalent during summer vacations. In spite of these reminders and the existing standards there are still reported pool which can harm swimmers. On a 2013 report by Kara David and Marc Jayson Cayabyab two swimming pools in Manila, Dapitan Sports Complex and Army and Navy Club failed to satisfy the DOH microbial standard. The sampled water reads 6,000 bacterial colonies per milliliter (mL) compared to a 200 count per mL. It also failed another parameter test, the coliform count test. The two pools were analyzed to have 4 coliform colonies per 50 mL which do not conform to the 1 coliform colony per 50 mL standard. Fecal coliform is present in human or animal excreta meaning the two pools were contaminated. Accidentally swallowing contaminated water may result to water-borne disease.[7][8]

2.2.2 Skin and Ear related

In February 1999, 19 identified persons developed a rash that met the symptoms of Folliculitis, inflammation of hair follicles associated with Pseudomonas Dermatitis as examined by the Colorado Department of Public Health and Environment (CDPHE). All developed a rash with 14 developing a more severe rash lasting from two to six weeks. The outbreak may be caused by inadequate disinfectant level that is hardly monitored by off-site contractors which cannot regulate the pool operation instantly and also the lack of alert system.[9]

Another health report from Utah stated that 91% of the 265 identified swimmers suffered from skin rashes while the remaining 9% complained of earaches. Half of the 9% were diagnosed of acute otitis externa or swimmer's ear.[10] It is characterized by the inflammation of external auditory canal that is usually associated with water exposure often times recreational waters. An average of 8.1 out of 1000 persons who seek doctor's attention were diagnosed of

AOE by US health department. [11] Other indicative symptoms include fatigue, headache, muscle ache, burning eyes, and fever. Four of the patient were positive of P. Aeruginosa .[10]

2.2.3 Algal bloom

From 2009-2010, 11 harmful algal bloom HAB) outbreaks in recreational waters were reported in the US. These HAB outbreak cause health problems, dermatological, respiratory, gastrointestinal, and neurological signs and symptoms [12]

2.3 Water Sampling and Analysis

2.3.1 Sensors used for pool water monitoring

2.3.1.1 pH Sensor

Figure 2.3: This shows the Atlas Scientific pH development test kit. The 4 bottles on the right are the pH calibration solutions. The pH probe is the golden tube-like probe on the left. The pre-assembled BNC connector is the white one at the center. Beside it is the small red circuit which is the pH circuit.

Atlas Scientific which converts human devices into robot ready devices has environmental sensors which are needed for this study [13]. The pH development test kit includes calibration solutions specifically of pH 4.0, 7.0 and 10.0, pH probe and pre-assembled Bayonet Neill-Concelman (BNC) connector and pH circuit. The pH circuit reads pH ranging from pH 0.001 to pH 14.000 from the pH probe. Calibration solutions contains constant pH values and has the capability to resist changes in that pH level. There can be small discrepancies in the output of the electrodes over time. To mitigate this difference, the sensor must be periodically calibrated [14]. Calibrations are usually done near the isopotential point which is the point where the pH value at which dE/dt for a given electrode pair is zero produced by the electrode [15]. The isopotential point of pH is at pH 7.0 (0mV) at 25 degrees Celsius. This is where primarily the calibration is performed and secondarily at either pH 4.0 or pH 10.0. It is recommended that calibration at two pH values at either side of the expected pH must be done prior to pH measurement [14]. The pH probe reads pH range of 0-14. It has a response time of 95% in 1s and it can handle a max pressure of 100 psi. The normal swimming pool pressure is about 10 psi [16]. This probe can handle the pressure and its recalibration time is yearly. It can be submerged in water for a max depth of 60m. However, the cable length of this sensor is only 1 m. The pH probe thus, can only be fully submerged for up to the BNC connector. It is advisable to submerge the probes at 450mm below water surface. [6] It weighs 49 grams, light enough to be incorporated in the surface water device. The tip of the pH probe is a glass membrane. This glass membrane permits hydrogen ions from the liquid being measured to diffuse into the outer layer of the glass, while larger ions remain in the solution. The difference in the concentration of hydrogen ions (outside the probe vs. inside the probe) creates a very small current. This current is proportional to the concentration of hydrogen ions in the liquid being measured [17].

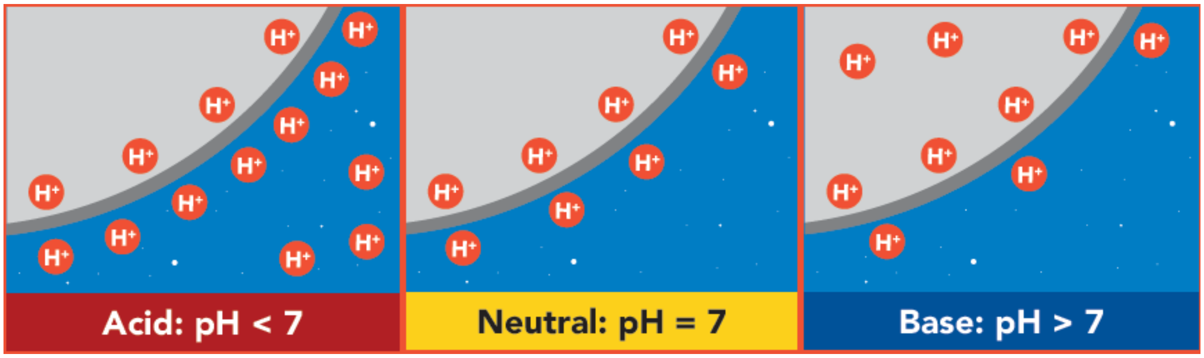


Figure 2.4: This shows that at certain pH levels, hydrogen ions will penetrate the glass membrane of the Atlas Scientific probe.

2.3.1.2 ORP sensor

Figure 2.5: This shows the Atlas Scientific ORP/REDOX test kit. The 2 bottles on the right are the ORP calibration solutions. The pH probe made of a platinum rod is the yellow tube-like probe on the left. The pre-assembled Female BNC connector is the white one at the center. Beside it is the small blue circuit which is the ORP circuit.

Atlas Scientific ORP/REDOX test kit include calibration solutions, ORP probe, pre-assembled female BNC connector and ORP circuit. The ORP calibration solution is designed to accurately calibrate the ORP probe. Unlike pH calibrations, which are generally done using two calibration buffers, ORP calibrations are almost always single point calibration caused there is no internationally recognized ORP calibration standard. That's why Atlas has only one calibration solution provided [18]. The ORP probe must be placed in this solution for 1 – 2 mins. To test if the probe was calibrated properly, the meter must read 225mV. The EZO ORP circuit maintains the stability and accuracy of the readings. The ORP probe can read ORP values ranging from -2000 mV to +2000 mV. It has a response time of 95% in 1s and can withstand a max pressure of 100 psi. It can handle temperature ranging from 1 degree Celsius to 80 degrees Celsius. It needs to be recalibrated yearly. The same as the pH probe, the ORP probe can be fully submerged in swimming pool water up to the BNC connector. Oxidation is the loss of electrons and reduction is the gain of electrons. The output of the probe is represented in millivolts and can be positive or negative. Just like a pH probe measures hydrogen ion activity in a liquid, an ORP probe measures electro activity in a liquid. The OPR reading represents how strongly electrons are transferred to or from substances in a liquid. Keeping in mind that the readings do not indicate the number of electrons available for transfer [19].

2.3.2 Aqua Lab Center for Laboratory Testing

. Aqua Lab Center is a Water Refilling Station business located in Del Monte Avenue, Quezon City Metro Manila. They started in 1997 as an ATT-Aqua Treatment Technology's Water Testing and Laboratory Department that cater its needs but later on they decided to launch the department as an independent and a full-pledge Company. With that, ATT (Aqua Treatment Technology) Aqua Lab Center was finally established. Aqua Lab Center is now one of the trusted centers for water analysis and water testing in the country. It has gained the much endeavored National Accreditation from the Department of Health (DOH) and the Accreditation of local governments for its trusty and reliable Microbiological; Physical and Chemical Analysis of potable water. Aside from this they also manufacture their own products such as disinfectants, water test kits and many more. Their microbiological testing includes testing of the total color form of the water and microorganisms found in it. For the physical and chemical testing, one of the laboratory testing they do is pH testing of water samples and testing of total chlorine and free chlorine coming from swimming pools. [20]

2.4 Software and Hardware

2.4.1 Raspberry Pi 3 Module

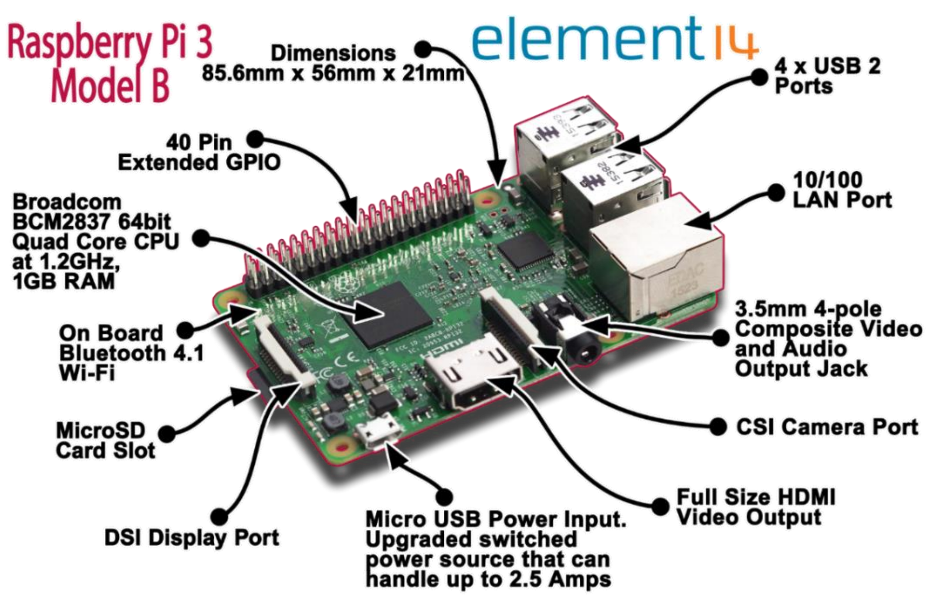


Figure 2.6. This shows the hardware design and parts labels of Raspberry Pi 3 Model B.

The Raspberry Pi (RPi), in general, is a small, cheap and handy computer which was made to achieve an affordable education in computers. It requires an SD card which functions as a hard drive for the RPi and certain required files must be installed and stored there for the RPi to work. RPi is simply powered through universal serial bus (USB) and its monitor can be hooked up using a television (TV) set or monitor via high-definition multimedia interface (HDMI) port. Setting this all up will allow the users to access the basic functions of a normal computer. Notably, RPi has only about 3 Watts of power consumption [21]. The Raspberry Pi 3 Model B is roughly 50% fast than RPi 2 since it has a quad-core 64-bit ARM Cortex A53 clocked at 1.2 GHz. Its random access memory (RAM) is 1 GB of LPDDR2-900 SDRAM and its graphics are provided through the VideoCore IV GPU. Additionally, RPi 3 now has an on-board 802.11n WiFi and Bluetooth 4.0. It can now be utilized for Internet of Things (IoT) and real-time data processing projects without the use of separate WiFi and Bluetooth modules [22]

2.4.1.1 Bluetooth Module

Raspberry Pi 3 has a built-in Bluetooth 4.1 module which features low duty cycle directed advertising that maintain connections with less frequent manual intervention. Bluetooth 4.1 devices can act as both hub and end point simultaneously. The current 4.0 protocol has a practical range of about 30 meters, but the new 4.1 protocol has an additional feature which will indirectly connect devices outside of that range through the cloud. Bluetooth 4.1 will go into routers, which can receive Bluetooth data and redirect it to cloud services via a basic software layer in the gateway equipment. This feature of Bluetooth 4.1 can be utilized for future improvements on the device. Moreover, rather than carry a fixed timeout period, Bluetooth 4.1 will allow manufacturers to specify the reconnection timeout intervals for their devices. This means devices can better manage their power and that of the device they are paired to by automatically powering up and down based on a bespoke power plan.

2.4.2 Utilizing Ninja Integrated Development Environment (IDE)

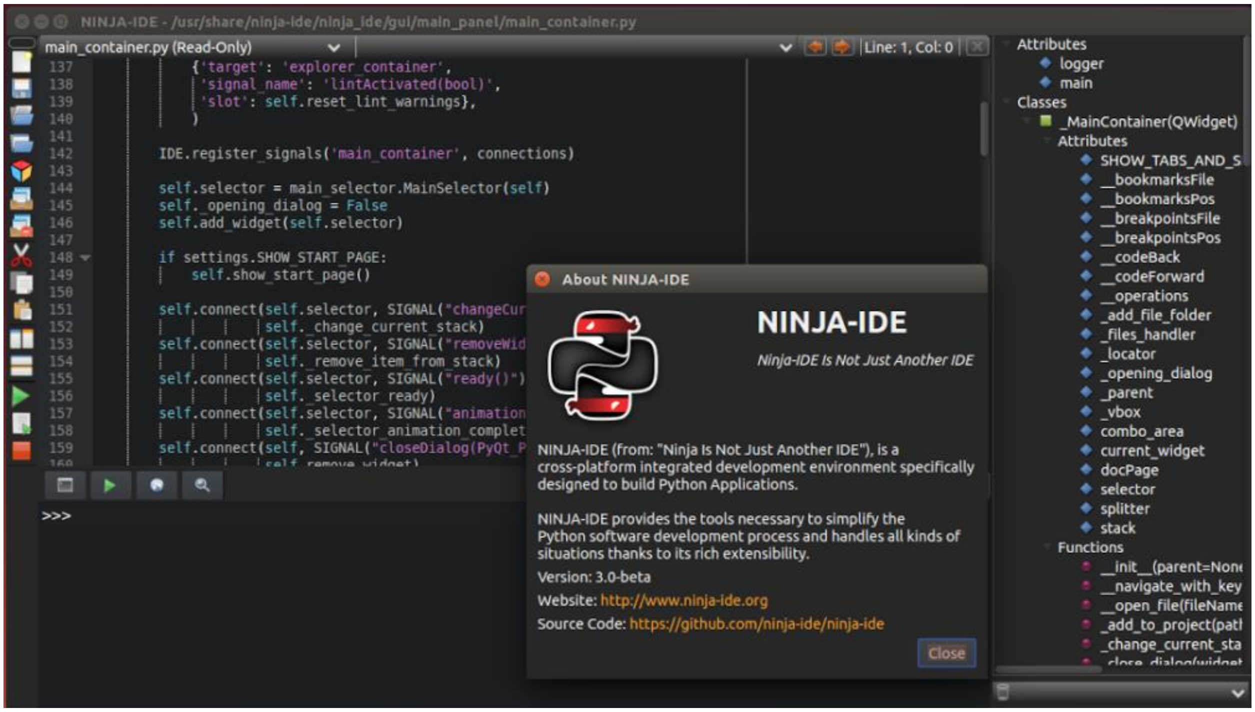


Figure 2.7: Ninja IDE Working Environment

Ninja IDE allows developers to create applications for several purposes using all the tools and utilities of NINJA-IDE, making the task of writing software easier and more enjoyable.. It provides a complete code editor with highlighting for several languages, code completion, and code assistant for: imports, navigation, etc.[23]

2.4.3 Utilizing mikroC PRO for calibrating the pH and ORP sensors

Figure 2.8. The figure shows mikroC PRO which will be used for calibrating Atlas pH and ORP circuit.

The mikroC PRO, developed by MikroElektronika for PIC, is a full-featured ANSI C compiler for PIC devices from Microchip. It is the best solution for developing code for PIC devices. It features intuitive IDE, powerful compiler with advanced optimizations, lots of hardware and software libraries, and additional tools that will help you in your work. Compiler comes with comprehensive Help file and lots of ready-to-use examples designed to get you started in no time. Compiler license includes free upgrades and a product lifetime tech support, so you can rely on help while developing. [24]

2.4.4 Thin-film-transistor liquid-crystal display (TFT LCD)

Figure 2.7: Resistive Touch Screen TFT LCD Monitor as seen in MakerLab-Electronics

A TFT LCD will be used on this device. Not only that this type of LCD presents bright and appealing colors but also utilizes low power consumption of 5 volts 90 mA. This has a resistive touch screen and industrial grade waterproof for outdoor display. The 3.5-inch LCD monitor has a resolution of 480x320. This will be connected via VGA from LCD to HDMI of Raspberry Pi. [25]

2.4.5. Power Supply

(a) **(b)**

Figure 2.8: Power Supply a.) packaging of 24,000 mah power bank b.) components inside a power bank

A power bank will be used for powering up the Popi. Since Popi is a wireless device floating on the entire pool hours on the surface water, it needs a high capacity power supply that can continuously power it up all day. The 24,000 mah power bank will be used in powering up Popi. It is portable, durable and has a Smart Switch technology which automatically decides when to charge a device and with what corresponding current. It has an output of 5V with two ports, one in 2.1A and the other in 1A. Its size is 16cm x 7cm x 3cm, fit for the dimensions of the Popi. The total time that the power bank is capable of powering the PoPi is approximately 10.78 hours. The power requirement for Raspberry Pi is 5 volts, 2.1 A, [26] for the LCD is 5 volts, 90 mA [27] and for the two sensors are 5 volt, 18.3 mA each.[28]

2.4.6 Flex Tape

Flex Tape is a super strong, rubberized, waterproof tape that can patch, bond, seal and repair virtually everything. It is specially formulated with a thick, flexible, rubberized backing that conforms to any shape or object. Furthermore, it can be applied hot or cold, wet or dry, even underwater. Moreover, it instantly seals out water, air and moisture to create a super strong, flexible, watertight barrier. [29]

2.5 Possible Adverse Health effects of certain pH/chlorine level

2.5.1 Eye irritation pH level

<table>
<tr><th colspan="2">pH and its Effects</th></tr>
<tr><th>Water Quality Effect</th><th>pH</th></tr>
<tr><td>Chlorine Disinfection Poor
Eye Irritation
Skin Irritation
Staining of Plaster
Growth of Algae
Reduced Effectiveness of Bactericide</td><td>>8.0</td></tr>
<tr><td rowspan="3">Most Ideal for Eye or Skin Comfort and Disinfection</td><td>7.8</td></tr>
<tr><td>7.6</td></tr>
<tr><td>7.2</td></tr>
<tr><td>Eye Irritation
Skin Irritation
Corrodes Pipes
Etching of Plaster
Scale Forming</td><td><7.0</td></tr>
</table>

Table 2.1 shows the pH level and its corresponding effects

A symptom of Corneal Edema, or the swelling of the cornea caused by inflammation, infection and other various diseases, was said to be present on the eye examinations done on 50 people instantly before and after they swam in a chlorinated pool water. It was found out that 34 pool goers saw circles of rainbows around the light after swimming which is said to be a symptom of corneal edema. By slit-lamp examination, forty-seven of these pool goers experienced corneal epithelial erosions, due to frequent scratching of the eye caused by chlorinated pool water [6]. In addition to this, one of the possible adverse health effect of both high and low pH level is eye irritation. It is said that the most appropriate and comfortable pH level for the human eye ranged from 7.2 to 7.8 pH. However, when the pH level goes below 7.0 or increases greater than or equal to 8, it is most likely to cause eye irritation to pool goers [4].

2.5.2 Skin irritation redness and itchiness

Skin irritation is one of the possible adverse health effects that pool goers might obtain when swimming in unmaintained pool water. When the pH level of the pool gets higher than or equal to 8 or it gets lower than or 7, it is said to cause skin irritation [4]. A study shows that chlorine itself is not enough to harm the skin of the pool goers. Chloramine, one of the known compound present in the pool, is a mixture of chlorine and other bodily fluids like sweat, saliva, perspiration, urine etc. When these two substances are mixed, it is said that the ability of chlorine to eradicate bacteria weakens. Thus, contributing to a possible skin irritation [30].

2.5.3 Enamel Erosion on Teeth

Enamel erosion occurs when the water is acidic specifically when the pH is at 3.6. For 1 – 2 hours, a sectioned human tooth was submerged in pH levels higher than 3.6, the result showed that the enamel was not affected. However, using scanning electron microscopy (SEM) micrographs, honeycomb-like etch pattern were seen on the tooth surfaces when extensively immersed to pH level 3.6 of swimming pool water. This means that there was preferential loss of prism cores [31]. This preferential loss of prism cores denotes Type 1 etching. It also signifies cohesive failure of the dentin [32]. Dentin is one of the major components that surround the tooth pulp which serves as the connective tissue to the brain. This area is very sensitive to mechanical, chemical and thermal stimuli [33]. Thus, if the dentin is removed and the pulp is exposed, tooth sensitivity or pain shall be felt [34].

2.6 Possible Pool Damage cause by certain pH/chlorine level

2.6.1 Corrosion

Damage can take place in pool walls if pH in pool water is too acidic or in other words, the pH level is lower than 7. This pH level below 7 dissolves grout and plaster of a pool which contributes in making the pool surfaces rough. This can also cause concrete pitting corrosion and thus, corrode metal products like pipe fittings, swimming pool equipment and pump connections. That is why, one thing that should also be remembered is that when chlorine is added to the water and then you have a low pH level, the pool water can be very corrosive. [35]. In addition, the specific compound leading to corrosion is Chloramine. Chloramine, when left untreated, not only it may build up in water but also in the air when there is insufficient air circulating around the pool [36]. As pH level drop to below seven, the water becomes acidic, that may cause corrosion. Long exposure to water under 6.5 pH level may cause corrosion on metal, pipes, and ceramic tiles [2].

2.6.2 Pool Stain

One problem that can occur with low pH level is staining of pool walls and concrete pitting. In addition to this, the level of alkalinity can also contribute to this problem. The level of alkalinity in one's pool helps with many things. Some say that when the alkalinity level was increased, it helps in the prevention of algae formation. But then, when the pH level becomes low which can cause concrete pitting corrosion, low alkalinity can also occur from the corrosive water which can contribute in staining of pool walls [35]. Too much metal content in the pool water can also contribute in pool stain leading to staining of the pool basin and causing discolored pool water [37]. Copper, a chemical element which is also a metal, is said to be used in pool products that act as an algaecide which can kill algae if properly used but can stain pool surfaces when not properly used. [35]

2.6.3Algae

Algae are small organisms that multiply rapidly and can form slimy, green floating material or coat surfaces. They are very common organisms brought in by rain, wind, soil or even swimwear and cleaning equipment. [38] Swimming pools can turn green after rain showers because of infusion of nitrogen-enriched rain that provides perfect breeding ground for algae. If left unchecked, a crystal clear swimming pool can turn green almost overnight if an algal bloom occurs. At that point, the water will be unusable for days because of the clean-up procedures. [39] The presence of algae is an indicator that free chlorine is not being properly maintained. [38] Algae spores can be blown into the pool or be introduced by contaminated swimwear. In short, algae are always in the pool and can bloom into a visible colony when conditions are met. Conditions that may cause algae are poor water circulation meaning low flow or dead spots in the pool, poor water balance when pH and chlorine levels are not maintained at normal levels, poor water sanitation when there is low or inconsistent chlorine levels in pool and poor water filtration when there is show filter run times or the filter itself is ineffective. [40]

Chapter 3

METHODOLOGY

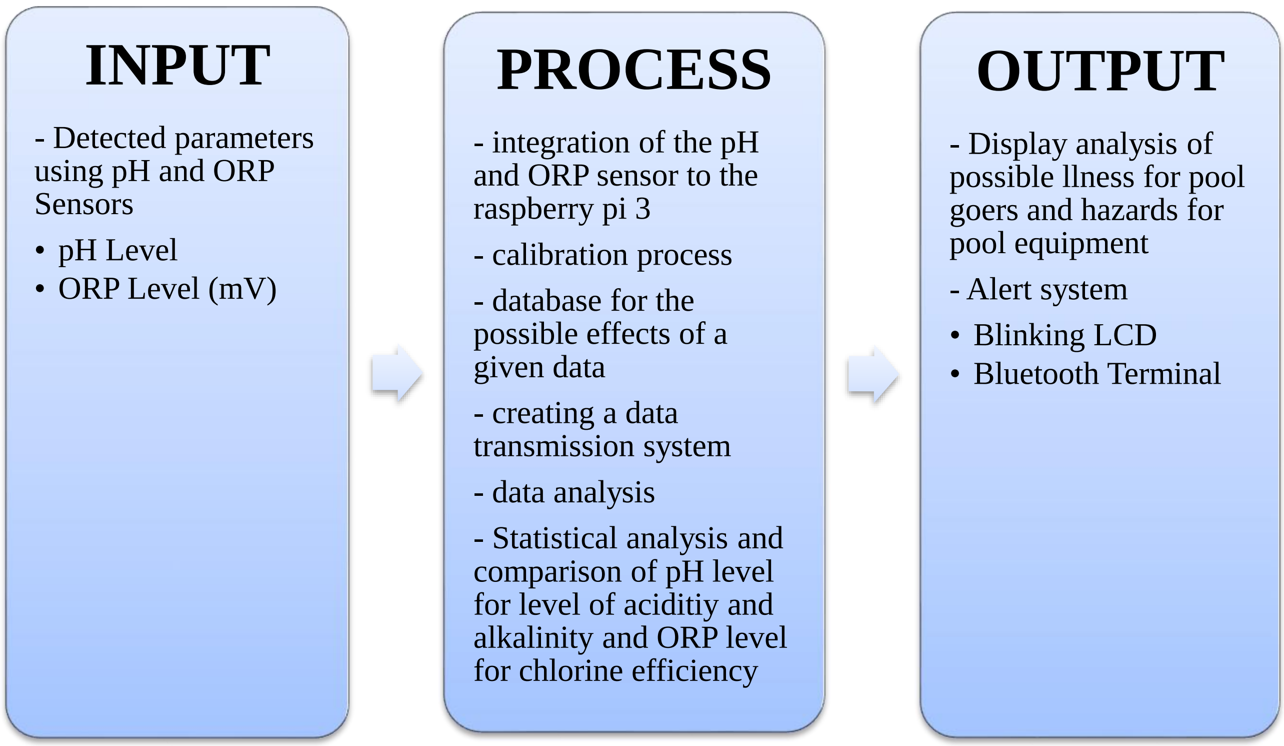


Figure 3.1: Conceptual Framework

Figure 3.1 shows the conceptual framework of the Swimming Pool Monitoring System where the inputs will be coming from the acquisition of pH level and ORP level for chlorine efficiency. For the process block, there will be a calibration process for the pH and ORP sensor connected to the Raspberry pi 3. Under these, a database will also be created for the possible effects of the given data which will be transmitted after for data analysis. The Raspberry Pi 3 will do the process for analyzing and comparing the gathered results. The outputs will display the possible illness and pool hazards through the use of the LCD and Bluetooth terminal. The LCD will blink endlessly and will only stop and display the results when its screen is touched.

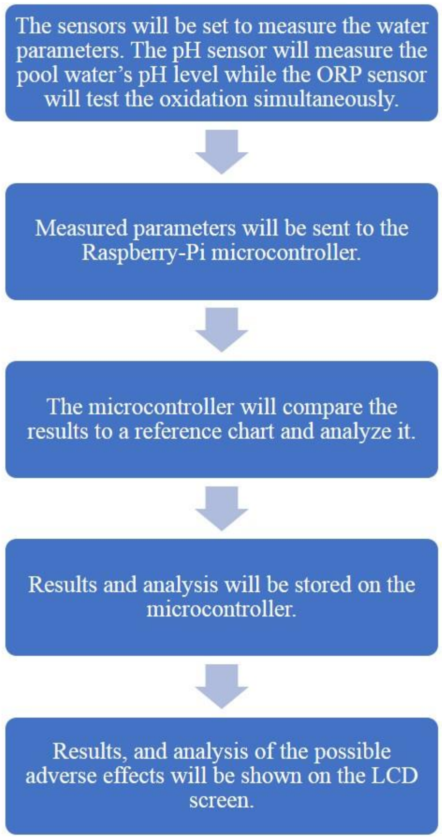
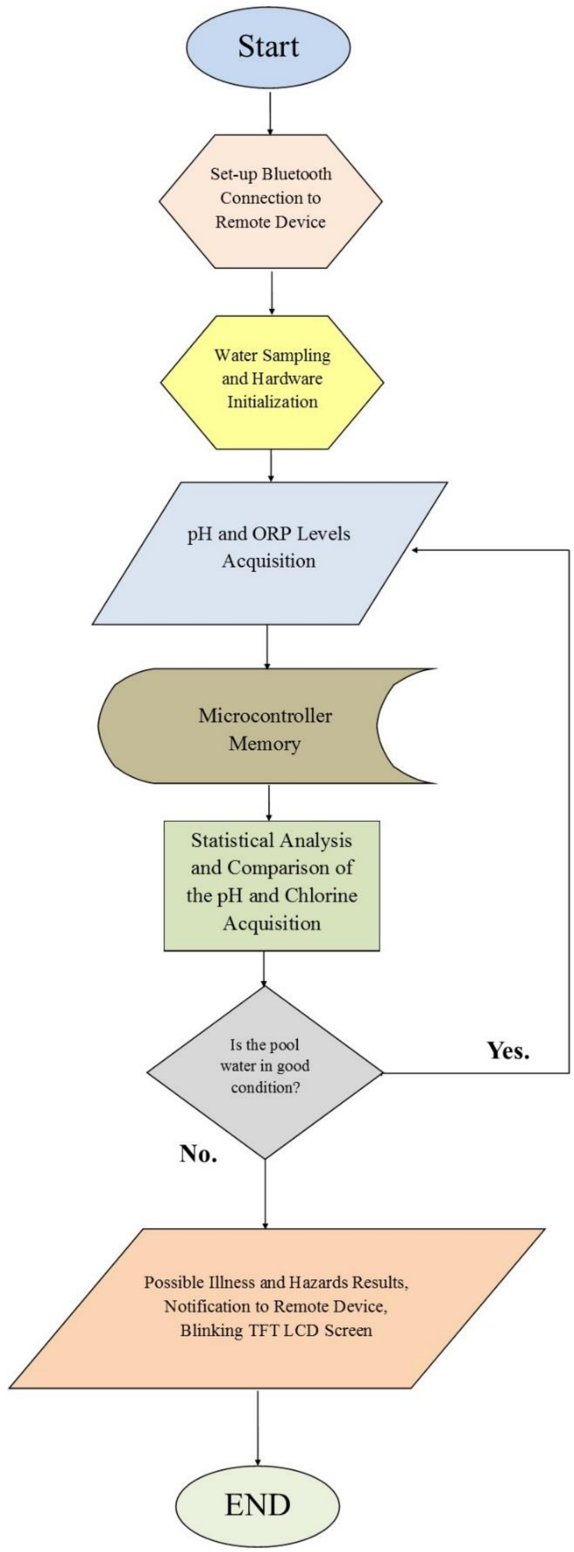


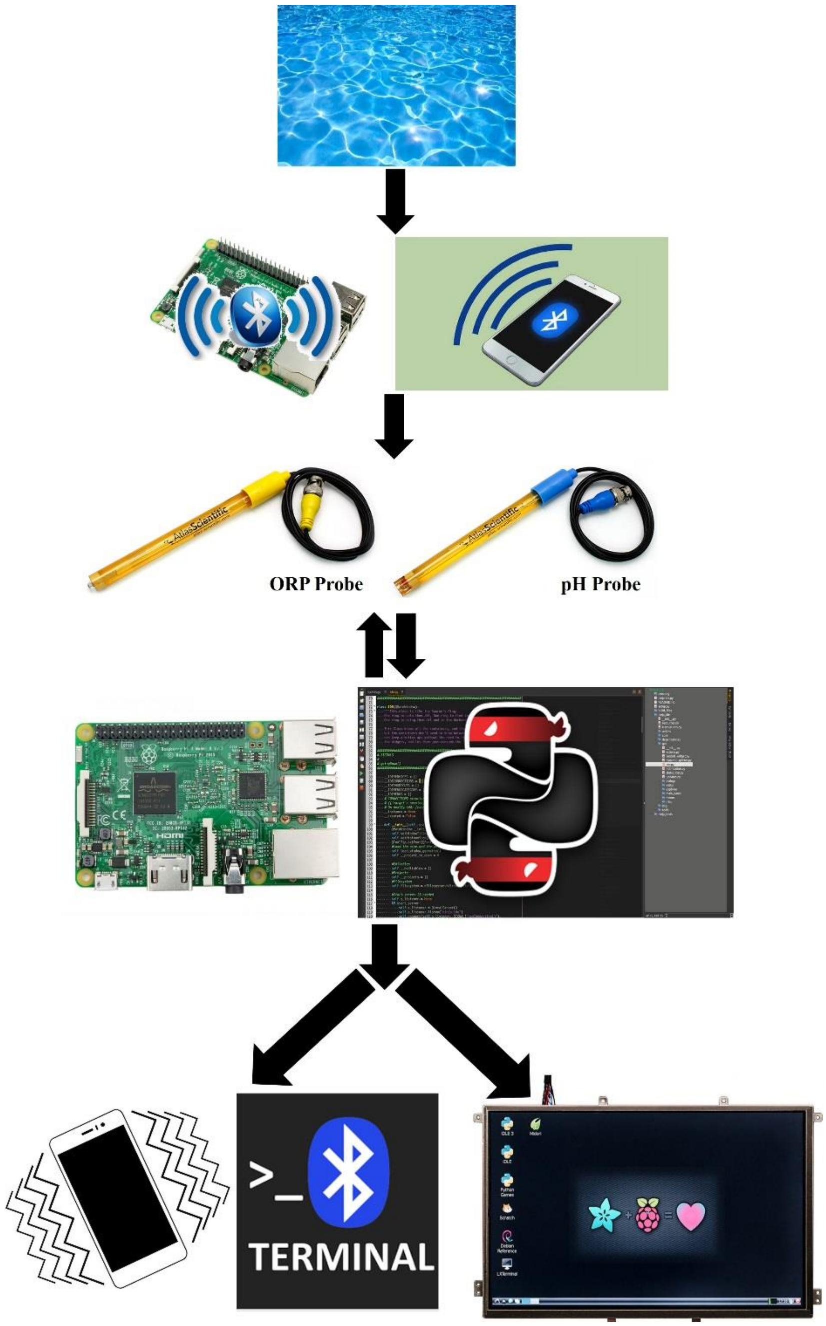
Figure 3.2: Process Flow of Swimming Pool Monitoring System

The process depends on the capability of the Raspberry-Pi microcontroller for the analysis of the parameters that will be measured by the pH sensor and ORP sensor. The measured values and data analysis will be stored on the microcontroller as directory.

3.1 Development of a microcontroller based prototype which utilizes pH and ORP sensors for data gathering of pH and chlorine level



(a)



(b)

Figure 3.3: (a) Flow Chart and b.) Conceptual Framework of Data Transmission

The process in Figure 3.3a shows how the program processes the acquired pH and ORP level and the information extracted from it, while Figure 3.3b shows how the information is transferred from one medium to another.

3.1.1 Pool Water Monitoring

3.1.1.1 Raspberry Module

Figure 3.4: Raspberry Pi 3 Module

The Raspberry Pi 3 is the main controller that is used for real-time pool water monitoring process of the study. It is responsible for processing the data gathered by the pH and ORP circuits. Based on the acquisition of pH and ORP levels, the module is programmed to interpret the data and display the possible adverse health and pool information. Also, it is programmed in such a way in which it will deploy an alert system via blinking LCD screen and Bluetooth terminal which will indicate that the status of the pool water is already high in pH level or insufficient in chlorine efficiency.

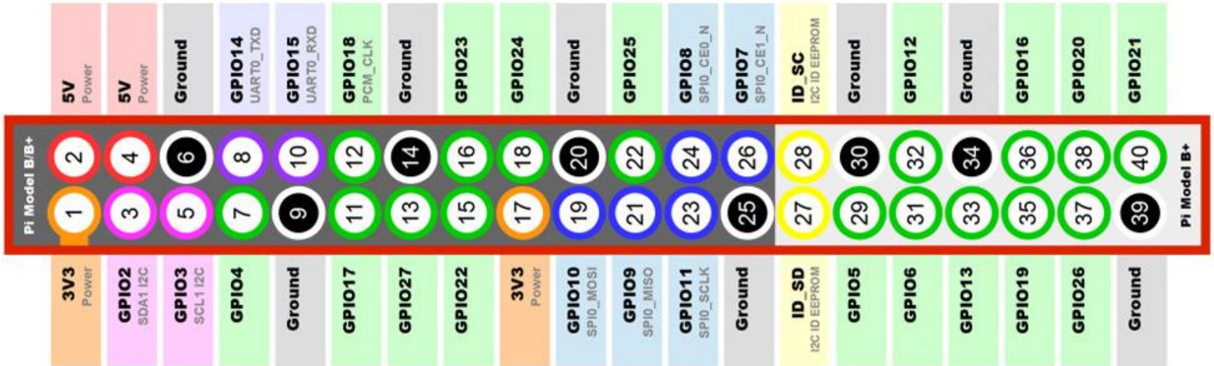


Figure 3.5: General Purpose Input/Output (GPIO) Pinout Assignments of the Raspberry Pi 3 Module

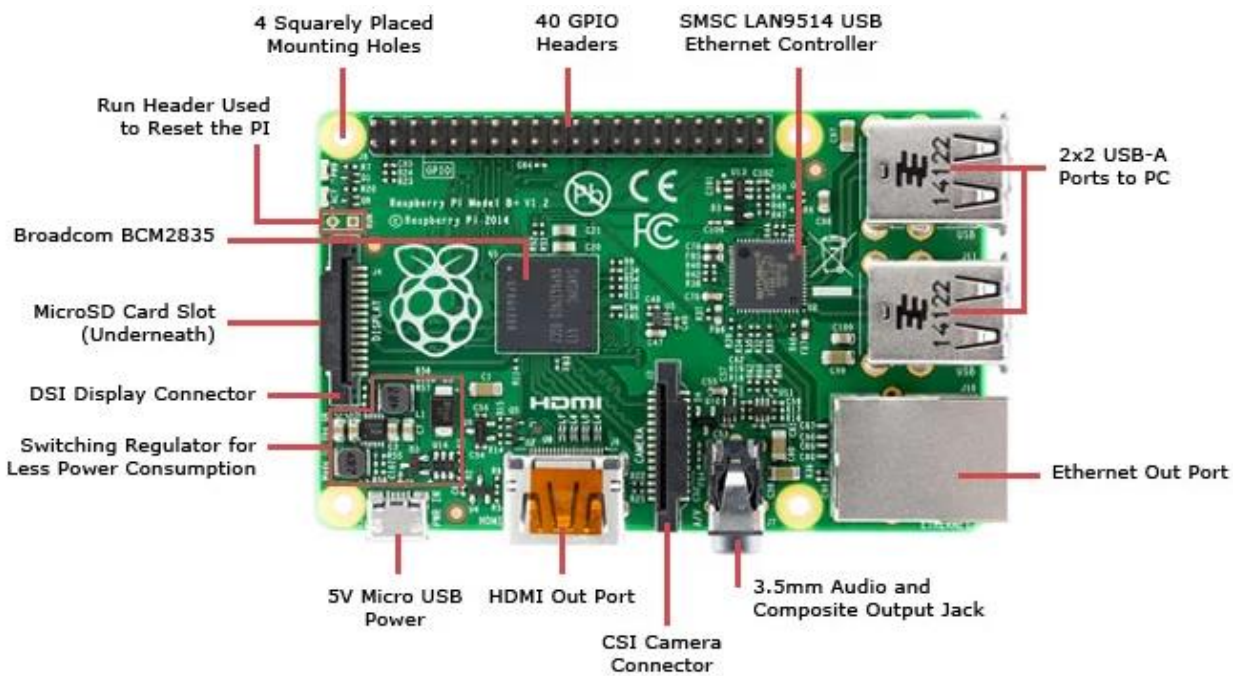


Figure 3.6: Parts of Raspberry Pi 3 Model B

Figure 3.5 shows the GPIO pinout assignments of the raspberry pi 3 which are used to as physical interfaces between the raspberry pi and the outside world. Figure 3.6 shows the labels of the parts of raspberry pi 3 model B which will be used as the microcontroller for the actual device in Figure 3.9.

Table 3.1: Raspberry Pi 3 Microcontroller Specifications

Raspberry Pi 3 (Single-Board computer with wireless LAN and Bluetooth connectivity)

SoC (System-On-a-Chip)	Broadcom BCM2837
CPU	Quad Core 1.2GHz 64bit CPU
GPU	Broadcom VideoCore IV
RAM	1GB RAM
Networking	BCM43438 wireless LAN
Bluetooth	Bluetooth Low Energy (BLE) on board
Storage	MicroSD
GPIO	40-pin extended GPIO
Ports	4 USB 2 ports 4 Pole stereo output and composite video port Camera Serial Interface (CSI) camera port for connecting a Raspberry Pi camera Display Serial Interface (DSI) display port for connecting a Raspberry Pi touchscreen display Micro SD port for loading your operating system and storing data Full size HDMI

The microcontroller’s hardware provides reliable performance for the analyzing and processing of readings coming from the connected sensor circuits. The built-in Bluetooth 4.1 module of the Raspberry Pi 3 will also be utilized for the alert system that will be implemented.

3.1.2 Sensors

3.1.2.1 pH sensor

(a)

(b)

(c)

(d)

Figure 3.7: Atlas Scientific pH development test kit a.) BNC connector b.) pH probe c.) pH circuit d.) Calibration Solution

For the pH level to be measured, the pH sensor from the Atlas Scientific pH development test kit will be use together with the pH calibration solution specifically of pH 4.0, 7.0 and 10.0, pH probe, pre-assembled BNC connector and pH circuit. Calibration at two pH values at either side of the expected pH must be done first prior to pH measurement for the probe to recognize the pH levels and then accurately measure the pH level of the pool water after. The pH calibration solution will be responsible for calibrating the pH probe before testing it to the pool water. It contains constant pH values and has the capability to resist changes in the pH level. The first calibration will be performed at the isopotential point of pH which is at pH 7.0. The second calibration will use the pH calibration solution of either pH 4.0 or pH 10.0. After calibrating the pH probe, it can now be fully submerged into the pool water up to the BNC connector indefinitely. The pH sensor will be responsible for acquiring the pH level of the pool water which will then be compared to the ideal range of pH level that helps in keeping swimmers comfortable in the pool. From the pH probe, the pH circuit will then read the pH ranging from pH 0.001 to pH 14.000. Thereafter, the pH sensor reading will be analyzed and processed using the Raspberry Pi 3 module.

3.1.2.2 ORP sensor

(a)

(b)

(c)

(d)

Figure 3.8 Atlas Scientific ORP/REDOX development test kit a.) Female BNC connector b.) ORP probe c.) ORP circuit d.) Calibration Solution

For the measurement of chlorine level, ORP sensor from the Atlas Scientific ORP/REDOX test kit will be used together with the ORP calibration solutions, ORP probe, pre-assembled Female BNC connector and the ORP circuit. The ORP calibration solution will be responsible for calibrating the ORP probe first for about 1 to 2 minutes prior to measuring the ORP level of the pool water. To examine if the probe was properly calibrated, a reading of 225 mV must be read by the meter. The ORP circuit is designed to maintain the stability and accuracy of the readings. After calibrating the ORP probe, it can now be fully submerged into the pool water up to the BNC connector same with the pH probe. The ORP sensor will be subject to obtaining the ORP level of the pool water that can read ORP values ranging from -2000 mV up to +2000 mV. This reading is to be compared to the acceptable range of ORP levels in the pool. The ORP sensor reading will then be analyzed and processed with the help of the Raspberry Pi 3 module.

3.1.2.3 Actual Set-up

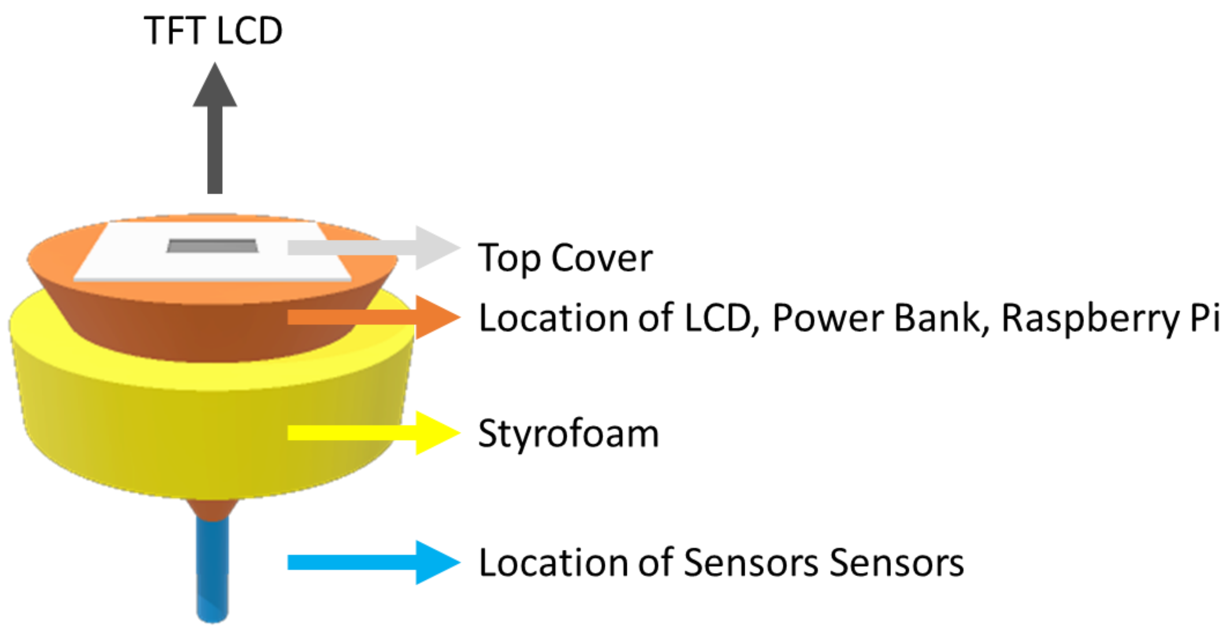


Figure 3.9: Proposed Design of the Device

The figure above shows the design of the device that will be used for this study. This device will be called Popi. “Po” coming from the word “Pool” and “pi” from the microcontroller “Raspberry Pi”. This device will monitor the status based on pH and ORP of a swimming pool and will inform the user of possible health effects.

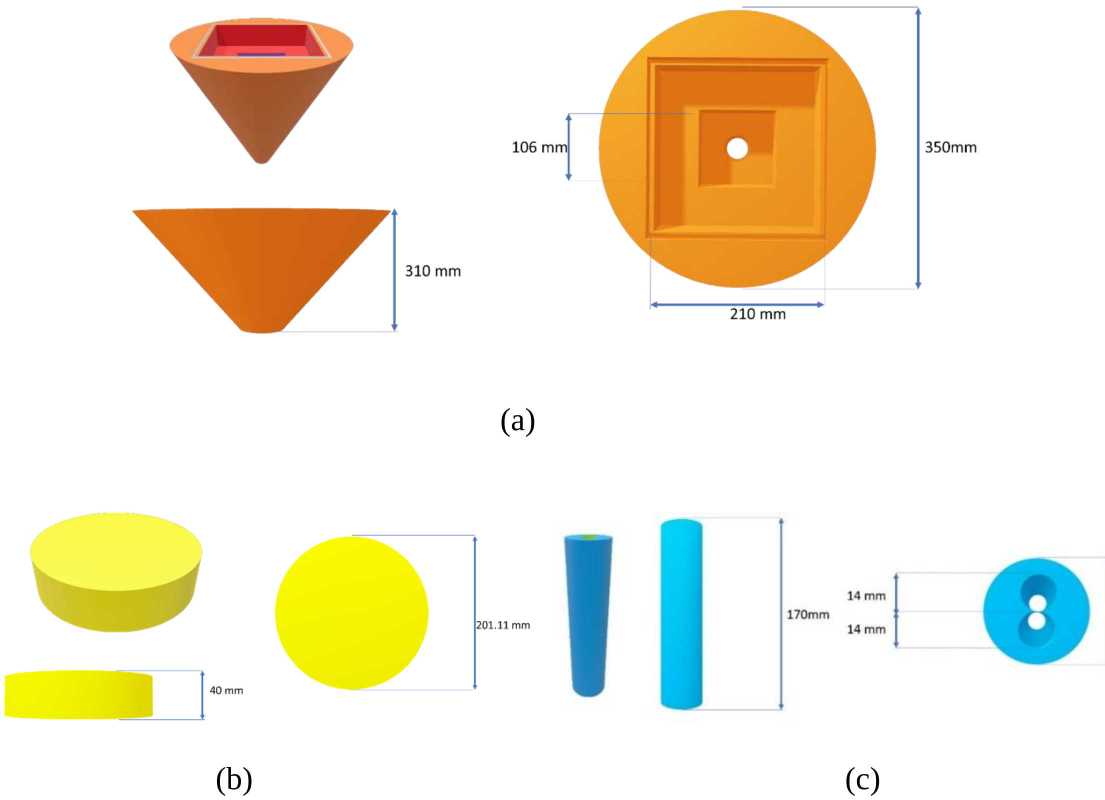


Figure 3.10: Proposed Dimension Labels of a.) Location of Raspberry Pi b.) Floaters c.) Location of Sensors

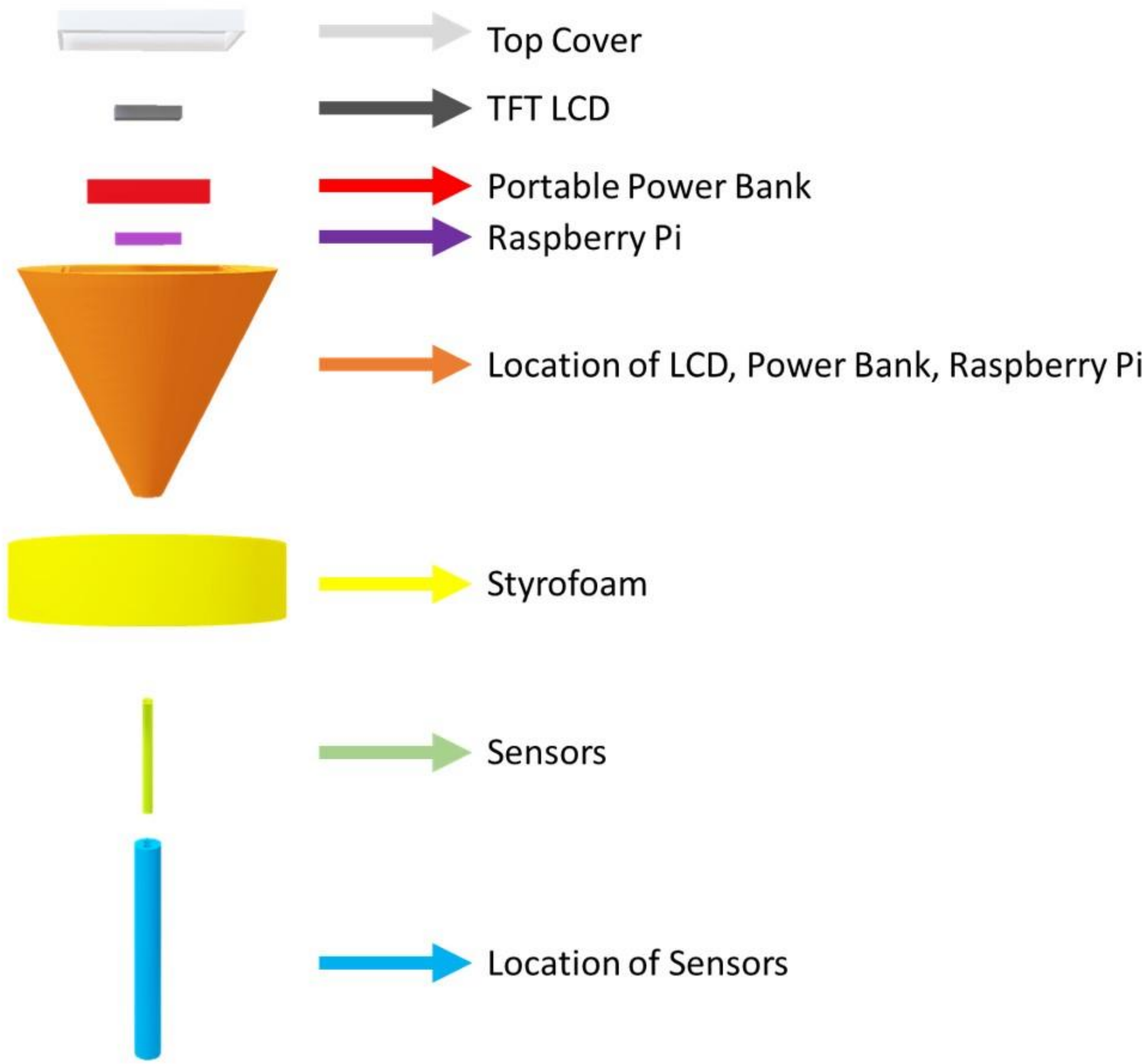
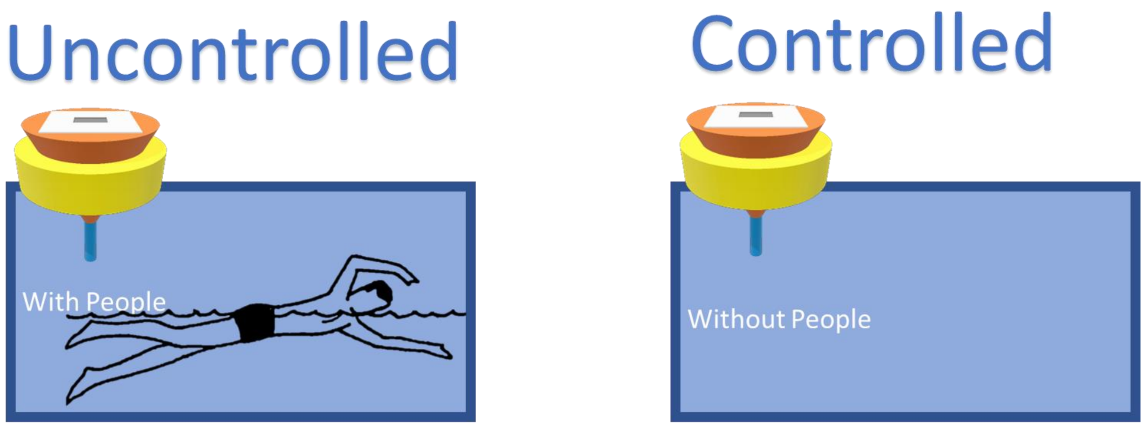


Figure 3.11: Exploded View of the Proposed Device

The image above shows the final product of the proposed system. Most of the materials that is used for this casing will be manufactured using a 3D printer which uses a plastic filament as its main material. The TFT LCD is placed on top of all the components so the user can easily see data that the device had gathered. The main body of the device is an inverted hollow cone wherein the Raspberry Pi and the power bank is placed. The sensors are in a cylinder connected to the body. The cylinder contains a pair of holes at the bottom so that the sensors could get water samples from the pool. The casing is designed properly so that only the sensors are submerged in water reducing the chance of water getting into the main body. The Styrofoam Cylinder serves as the floaters to avoid the Raspberry Pi being submerged under water. The body is made to be airtight so that in the event wherein the device is fully submerged, water would not easily get into the device.



(a) **(b)**

Figure 3.12: Acquisition of parameters in a.) uncontrolled and b.) Controlled Pools

The figure above shows the type of pool where the device will be tested. In an uncontrolled, the pool will consist number of pool goers that may be the cause of the change of the chlorine level that is present on the pool. On the other hand, controlled pool means that the pool has a constant range of ORP level without any factors that would drastically change the level of ORP.

3.1.2.4 Calibration Testing per sensor

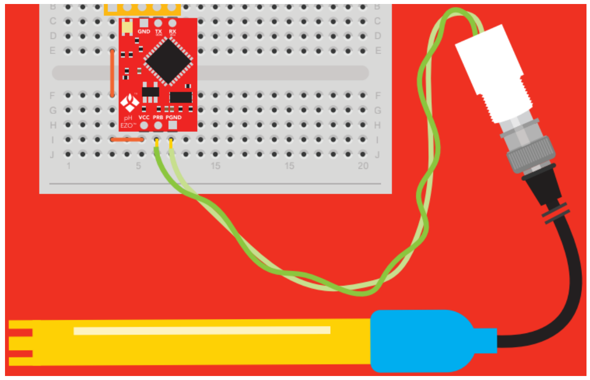


Figure 3.13. The figure shows the connection of the pH circuit, BNC connector and pH probe. [See Appendix B]

For both pH and ORP sensor, the sensors function the same. They only differ on what parameter they are measuring. The sensors are needed to be calibrated first for the probe to recognize the pH or ORP level and to ensure accurate measurements of the said parameters in the pool water thereafter. These values will now be the baseline values which will be used to compare with the values to be obtained from the pool water.

For calibration process of pH and ORP probe, the researchers will use a program utilizing MikroC [24]. The said software will be used to program the Raspberry Pi microcontroller connected to the pH circuit. The pH circuit, BNC connector and pH probe are connected as shown in Figure 3.12. Same connection will be followed for the ORP setup. Then, the probe will be placed in the calibration solution. The calibration instruction given by Atlas Scientific will be followed [See Appendix A]. The pH/ORP circuit, connected to the BNC connector of the probe, will be the one to monitor and provide the readings of the known solution. The readings will then be seen on the interface of the software to verify if it was properly calibrated. To verify if the probes are properly calibrated, the percentage error for each trial in Table 3.2 will be determined.

Percentage error is used in comparing an approximate value to an exact value. The formula of the percentage error is,

$$\boldsymbol{Percentage\ Error} = \left|\frac{\boldsymbol{Theoretical\ Value - Experimental\ Value}}{\boldsymbol{Theoretical\ Value}}\right| \times \mathbf{100}\%$$

Figure 3.13. Formula for Percentage Error

According to North Carolina State University, when comparing an experimental value to a theoretical value or accepted known value, the difference between the experimental value and the theoretical values are determined by the percentage of the theoretical value. Moreover, "There is no upper limit on a "percent error". There is only the necessary (human) judgment on whether the data is refers to can be useful or not." (Cooke, 2017). In order to accept the value of the pH/ORP sensor reading in Table 3.2, the researchers set the acceptable percentage error to 5%. If the percent error is more than 5%, recalibration will be done. If after recalibration and the percent error is still more than 5%, according to Atlas Scientific, the probes have no maintenance. [See Appendix C, Appendix D] Therefore, the values of the data gathered from the probe will be calibrated in the program using Ninja IDE. The code to be written will adjust the values to the actual value. E.g. The probe read pH 7.20 but the actual value is supposed to be 7.40. The code will adjust it by adding +0.20.

Table 3.2: Calibration testing of pH level using the pH sensor and pH calibration solution from Atlas Scientific pH development test kit.

Trials	pH Sensor reading	Actual value of pH calibration solution

Trial 1		**4**
		7
		10
	pH Sensor reading	**Actual value of pH calibration solution**
Trial 2		**4**
		7
		10
	pH Sensor reading	**Actual value of pH calibration solution**
Trial 3		**4**
		7
		10

Table 3.2 shows the comparison of the acquired pH sensor reading from the actual value of the pH calibration solutions specifically pH 4, 7, and 10.

3.1.3 Statistical Analysis

As one controlled and three uncontrolled pool setups were tested, the results of each tested setup are taken into a statistical analysis for comparison with the results of other setups.

$$Mean = \sum \frac{x_n}{n}$$

Where:

N=$Number\ of\ Samples$

x_n=$sample\ value\ at\ n$

Figure 3.14: Equation for Mean Value of a Data Set

Figure 3.14 shows the equation used to obtain the arithmetic mean of the values within a data set.

$$\sigma = \sqrt{\frac{\Sigma(\mathrm{Mean} - \mathrm{xn})^2}{\mathrm{N} - 1}}$$

$where$:

$Mean$=$arithmetic\ mean\ of\ the\ Data\ set$

x_n=$nthsample$

N=$Total\ Number\ of\ Samples$

Figure 3.15 Standard Deviation Equation for a Data Set

The Standard Deviation of the Data Set can be obtained using the Equation shown in Figure 3.15. The SD (σ) is used to measure of quantify the variation or dispersion of the values in the data set.

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where:

$MeanX1 = Mean\ of\ first\ data\ set$

$MeanX2 = Mean\ of\ second\ data\ set$

$\sigma 1 = Standard\ Deviation\ of\ First\ Data\ Set$

$\sigma 2 = Standard\ Deviation\ of\ Second\ Data\ Set$

$N1 = Total\ Number\ of\ Samples\ of\ First\ Data\ Set$

$N2 = Total\ Number\ of\ Samples\ of\ Second\ Data\ Set$

Figure 3.16: t-test Equation for 2 Data Sets

The Statistical test to be used in the study is a t-test, which is commonly used to compare two data sets with a small number of samples. The t test uses the equation shown in Figure 3.16.

$$p = 2 \cdot Pr(T > |t|) \quad \text{(two-tailed)}$$
$$p = Pr(T > t) \quad \text{(upper-tailed)}$$
$$p = Pr(T < t) \quad \text{(lower-tailed)}$$

Figure 3.17: shows the p-value or probability value which helps in determining the significance of the results when performing a hypothesis test in statistics

The p value of the data comparison can be obtained using a t-distribution table as a reference and using the t-value obtained using the equation the t-test equation finding the corresponding value of p using the relations shown in Figure 3.17.

For calibration testing:

The experimental value is the value of the sensor reading and the actual value is the value of the calibration solution for each of the testing of pH and ORP.

Null Hypothesis (Ho): There is no significant difference between the experimental value and the actual value.

Alternative Hypothesis (Ha): There is a significant difference between the experimental value and the actual value.

Table 3.3 Comparison of calibration testing with respect to pH reading

pH sensor reading Compared to Actual value of pH Calibration Solution in Calibration testing		
Number of samples for all N=3		
Actual value of pH calibration solution **Mean=** **Standard Deviation=**		
Trials	**Mean**	**Standard Deviation**
Trial 1 for pH 4,7,10		
Trial 2 for pH 4,7,10		
Trial 3 for pH 4,7,10		

Table 3.3 shows the statistical analysis of the pH sensor reading for each trial in comparison with the Actual value of pH calibration solution in calibration testing. The variation of pH sensor reading is analyzed by obtaining the mean and standard deviation.

Table 3.4: Calibration testing of chlorine level using the ORP sensor and ORP calibration solution from Atlas Scientific ORP/REDOX test kit

ORP	ORP Sensor Reading	Actual value of ORP calibration solution
Trial 1		**225 mV**
Trial 2		**225 mV**
Trial 3		**225 mV**

Table 3.4 shows the comparison of the acquired ORP sensor reading from the actual value of the ORP calibration solutions specifically 225 mV. The percent difference for each chlorine values for three trials is also shown that is needed for calibration testing. Unlike pH calibrations, which are generally done using two calibration buffers, ORP calibrations are almost always single point calibration caused there is no internationally recognized ORP calibration standard. That's why Atlas has only one calibration solution provided [10].

Table 3.5 Comparison of calibration testing with respect to ORP reading

ORP sensor reading Compared to Actual value of ORP Calibration Solution in Calibration testing
Number of samples for all N=3

Actual value of ORP calibration solution **Mean=** **Standard Deviation=**		
ORP	**Mean**	**Standard Deviation**
Trial 1,2,3 for ORP 225 mV		

Table 3.5 shows the statistical analysis of the ORP sensor reading in comparison with the actual value of ORP calibration solution in calibration testing. The ORP sensor reading is analyzed by obtaining the mean and standard deviation.

Table 3.6 Comparison of Experimental and Actual value of Calibration solutions

Parameter	**Actual Value**			**Experimental Value**				
	N	**Mean**	**Standard Deviation**	**N**	**Mean**	**Standard Deviation**	**T test**	**P value**
pH sensor reading								
ORP sensor reading								

In order to verify the results, the parameters for the pool specifically the pH and ORP sensor readings are taken into statistical analysis for verification if there is a significant difference between the experimental value and the actual value. Table 3.6 shows the statistical data for the experimental and actual value of calibration solution.

3.2 Determining the accuracy of the prototype through laboratory testing of the parameters being tested.

3.2.1 Mapua Laboratory testing for pH

Laboratory testing of the parameter being tested will be done by the researchers in order to determine the accuracy of the sensor being used for the prototype. For pH, the laboratory testing of the water sample will be done in Mapua University. The researchers will provide an instruction manual of the pH laboratory testing procedure to the Institutional Laboratory Management Office (ILMO). ILMO will verify the instruction manual and perform the necessary testing procedure. [See Appendix E]

Table 3.7: Verification of calibration of pH sensor by comparison with pH meter values

Trials	**pH Sensor reading**	**pH Laboratory Test Result**	**Percent Error**
Trial 1			
	pH Sensor reading	**pH Laboratory Test Result**	**Percent Error**
Trial 2			
	pH Sensor reading	**pH Laboratory Test Result**	**Percent Error**
Trial 3			

Table 3.7 shows the comparison of the acquired pH sensor reading from the pH laboratory test result. For each trial, different water samples will be tested. The percent error which should be less than 5% to be deemed acceptable is shown.

3.2.2 Aqua Laboratory Testing for ORP

Laboratory testing of the parameter being tested will be done by the researchers in order to determine the accuracy of the sensor being used for the prototype. For ORP, the laboratory testing of the water sample will be done in Aqua Lab Center. [20]

Table 3.8: Verification of calibration of ORP sensor by comparison with ORP laboratory test

ORP	ORP Sensor Reading	ORP Laboratory Test Result	Percent Error
Trial 1			
Trial 2			
Trial 3			

Table 3.8 shows the comparison of the acquired ORP sensor reading from the ORP laboratory test results. Same as for pH, for each trial, different water samples will be tested. Laboratory testing of water samples will be conducted at Aqua Lab Center. [20] [See Appendix F] The percent error which should be less than 5% to be deemed acceptable is shown.

3.3 Designing an alert system to indicate the possible adverse effect of the pool water condition

3.3.1 Data Analyzing using Raspberry Pi 3

3.3.1.1 Utilizing Ninja IDE

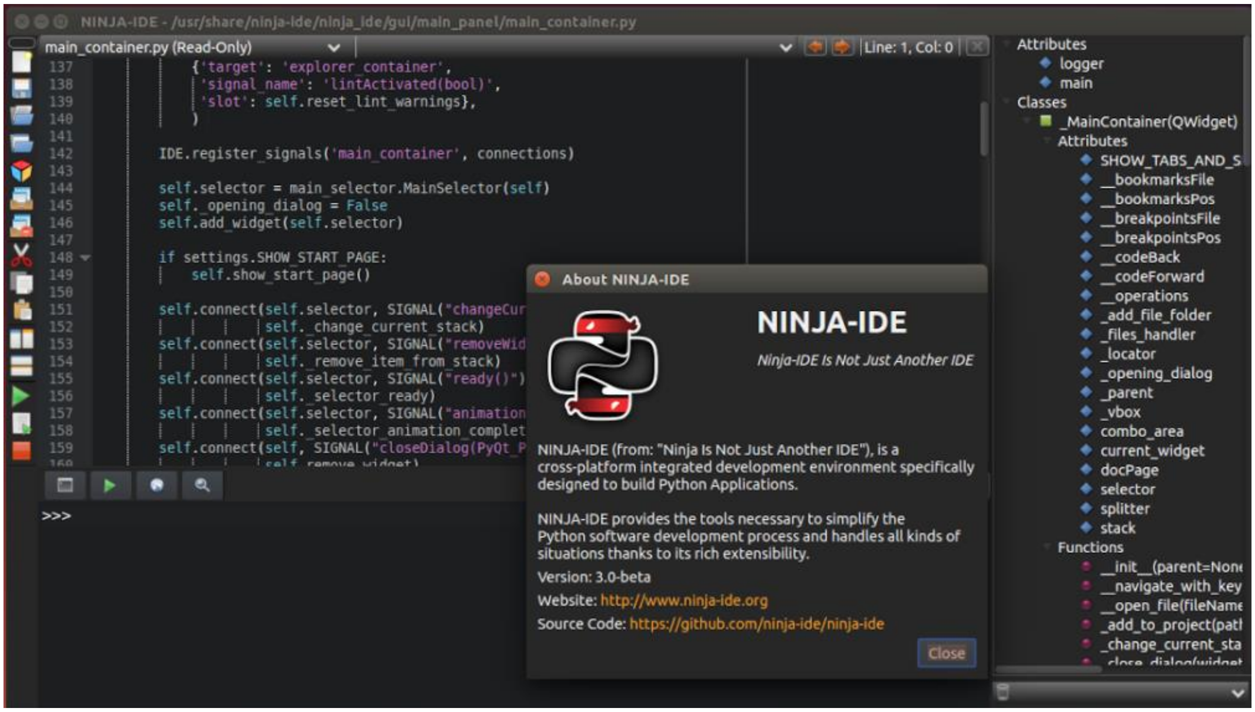


Figure 3.18 Ninja IDE Utilization

The Ninja IDE connected with the Raspberry Pi 3 will be utilized as the main software for programming the data gathered from the pH and ORP circuit. Using this software, the data gathered will be analyzed to interpret the possible adverse health effects and pool hazards. Both the readings of pH level and ORP level for chlorine and the analysis of the possible illness for pool goers and pool hazards will be shown on its interface.

3.2.1.1.1 Possible adverse health effects and pool hazards from pH and chlorine level analysis

After the sensors have read the status of the pool water, the acquired data is sent to the microcontroller to identify the possible adverse effects on health and pool equipment. The result of the information of adverse effects is generated with respect to the corresponding pH level that was gathered. While the effectiveness of the disinfectant and for possible bacterial growth will be based on the ORP level measurements. If the level of pH and/or ORP for a certain adverse effect was reached, then the microcontroller would output the information into the LCD. In the event when the pool water is very acidic or alkalinic, the microcontroller would activate the LED lights and transmit data to the remote device's Bluetooth terminal to established awareness.

3.3.2 Uncontrolled Testing

In this study, uncontrolled testing means acquiring data from operating swimming pools which includes swimmers. Three different swimming pools will be tested. Three trials will be performed for each pool to determine the accuracy of the pH and chlorine levels.

Table 3.9: pH and Chlorine Level Measurement for the three swimming pool

POOL 1	**pH sensor reading**	**ORP sensor reading**
Trial 1		
Trial 2		
Trial 3		
POOL 2	**pH sensor reading**	**ORP sensor reading**
Trial 1		
Trial 2		
Trial 3		
POOL 3	**pH sensor reading**	**ORP sensor reading**
Trial 1		
Trial 2		

Trial 3		

Table 3.9 shows the pH and ORP sensor reading of each pool for three trials under uncontrolled testing. These readings will then be compared to the readings of the table under controlled testing.

3.3.4 Pool Parameters Uniformity Testing for Uncontrolled Setup

In order to verify the accuracy of the results of the pH and ORP measured by the device, trials will be made from different points within the area of the swimming pool. Each trial's mean, min, max and standard deviation. Random points of at least 1 meter apart will be chosen in the swimming pool area.

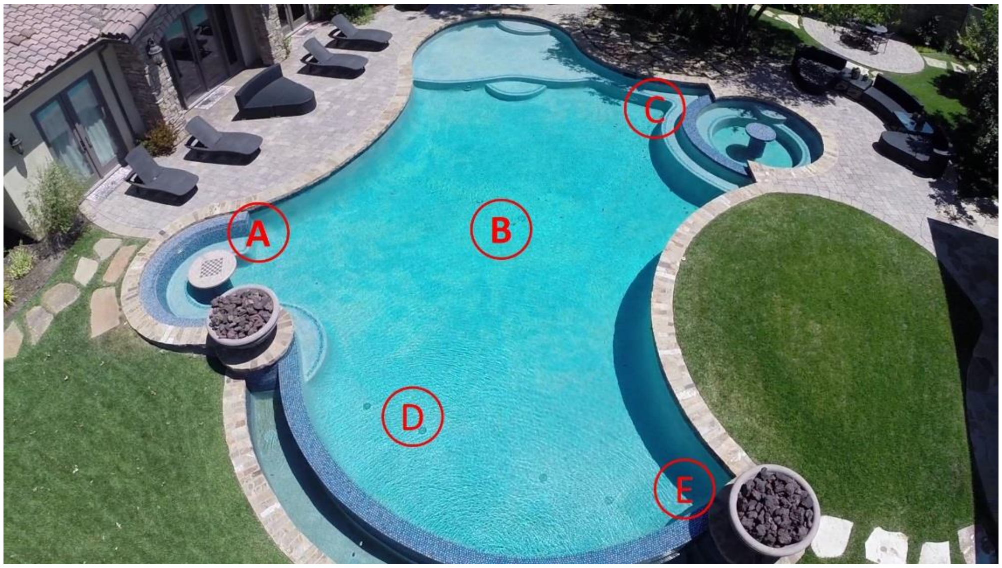


Figure 3.19: Sample Points in Pool Testing

Table 3.10: Parameter reading at different points inside the pool

Trial Points	pH sensor reading	ORP sensor reading (mV)

A		
B		
C		
D		
E		
Mean		
Min		
Max		
Standard Deviation		

Table 3.10 shows the pH and ORP readings at the surface and different point locations inside the pool.

The null and alternative hypotheses are shown below in lieu of the data in Table 3.11:

Null Hypothesis (Ho): There is no significant difference between the mean and the trial points.

Alternative Hypothesis (Ha): There is significant difference between the mean and the trial points.

Table 3.11: Statistical Table of Table 3.10

Parameter	Actual Value	Experimental Value	

	N	**Mean**	**Standard Deviation**	**N**	**Mean**	**Standard Deviation**	**T test**	**P value**
pH sensor reading								
ORP sensor reading								

Table 3.11 shows the statistical values of the parameters from table 3.10.

3.3.5 Pool Parameters Depth Testing for Uncontrolled Setup

To validate the claim that there is no significant difference between the parameters on the two depths in Figure 3.20, trials will be made from the surface water and the middle part. The surface water depth in this test is measured on the tip of the location of the sensors. Each trial's mean, min, max and standard deviation will be determined. Random points of at least 1 meter apart will be chosen in the swimming pool area. Trial points made in the uniformity testing will be the same in this test. However, there will be additional testing on the deeper portion of pool water specifically at the middle part.

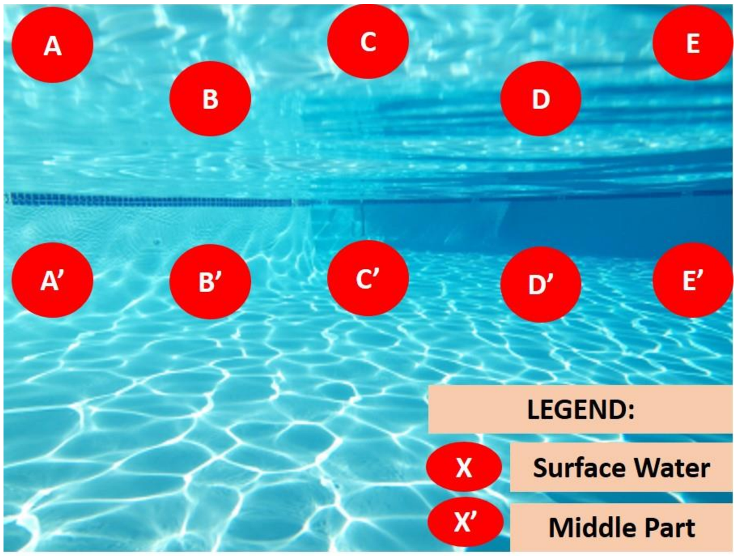


Figure 3.20: Sample Points in Depth Testing

Table 3.12: Parameter Reading at different points and Depth inside the pool

TRIAL POINTS			**PH SENSOR READING**		**ORP SENSOR READING**	
	X	**X'**	**X**	**X'**	**X**	**X'**
A						
B						
C						
D						
E						
MEAN						
MIN						
MAX						
STANDARD DEVIATION						

Table 3.12 shows the Ph and ORP readings from different points and depths inside the pool.

The null and alternative hypotheses are shown below in lieu of the data in Table 3.12:

Null Hypothesis (Ho): There is no significant difference between the surface water trials and the middle part trials.

Alternative Hypothesis (Ha): There is significant difference between the surface water trials and the middle part trials.

Table 3.13: Statistical Table of Table 3.12

Parameter	Actual Value			Experimental Value				
	N	Mean	Standard Deviation	N	Mean	Standard Deviation	T test	P value
pH sensor reading								
ORP sensor reading								

Table 3.13 shows the statistical values of the parameters from table 3.12.

3.3.3 Controlled Testing

In this study, one pool setup will be implemented in getting the pH and ORP level. To set a reference from the chlorine and pH values obtained from the uncontrolled setup, a controlled inflatable pool setup will be tested where pool water maintenance is recommended and advised to maintain a pH level ranging from 7.2-7.8 [3] and for ORP specifically on chlorine, the Center for Disease Control and prevention (CDC) suggest this concentration be maintained at least 2 parts per million (ppm) to provide the necessary disinfection [5]. This will serve as the basis for comparing the results from the uncontrolled setup to determine whether the possible adverse health effects were caused by internal or external factors.

The inflatable pool to be used in the controlled testing setup must have a height greater than 450 mm based from the minimum acceptable water depth to be tested which is measured 450mm below the surface water. [6] The width of the inflatable pool must be at least 350 mm for the proposed device to fit in the pool. Thus, the inflatable to be used has a dimension of 1880 x 460 mm with a capacity of 666 liters of water. Since the inflatable has a maximum capacity of

460mm, there will be no pool parameters depth testing for the controlled setup as it’s depth is considered as the surface water testing depth.

Figure 3.21: Sample Points in Pool Testing

Since pool parameters uniformity testing is a new experimentation in this proposed study, the researchers can only prove that there is no significant difference between different points in the pool area using the same testing procedure in the pool parameter uniformity testing of the uncontrolled setup, only that the trial points for the controlled setup are 60cm apart due to the small size of the inflatable pool.

Table 3.14: Parameter reading at different points inside the inflatable pool

Trial Points	pH sensor reading	ORP sensor reading (mV)
A		
B		
C		
Mean		

Min		
Max		
Standard Deviation		

Table 3.14 shows the pH and ORP readings at different point locations inside the pool.

The null and alternative hypotheses are shown below in lieu of the data in Table 3.11:

Null Hypothesis (Ho): There is no significant difference between the mean and the trial points.

Alternative Hypothesis (Ha): There is significant difference between the mean and the trial points.

Table 3.15: Statistical Table of Table 3.14

Parameter	**Actual Value**			**Experimental Value**				
	N	**Mean**	**Standard Deviation**	**N**	**Mean**	**Standard Deviation**	**T test**	**P value**
pH sensor reading								
ORP sensor reading								

Table 3.15 shows the statistical values of the parameters from table 3.14.

The groundwater pH level is in the range of 6-8.5. [6] The pH and ORP levels of the pool water will be tested first in order to verify if it is already in the desired levels of pH and chlorine efficiency. If the pool water pH and ORP levels are out of the desired range, then disinfectant solution must be added. Based from the chart [6], setting the pH 6.0 as an example of the initial pH level of the pool water, the computation of the amount of sodium carbonate (soda ash) to be added in the pool water to raise the pH level to 7.5 will be determined. Ratio and proportions will be used to determine the soda ash needed.

$$\frac{0.36\ kg\ of\ soda\ ash}{10,000\ liters} = \frac{X\ kg\ of\ soda\ ash\ needed}{666\ liters}$$

$$0.36\ (666) = 10{,}000X$$

$$X = \frac{0.36\ (666)}{10{,}000} = \mathbf{0.02}\ \boldsymbol{kg\ of\ soda\ ash}$$

After the soda ash is added and rest for 10 minutes to let the water absorb the product, the pool water will be tested to verify the levels of the pH and ORP. Results may vary due to difference in concentration of the sodium carbonate based on the chart and the commercially available ones.

Table 3.16: pH and Chlorine Level Measurement for the Inflatable Pool

POOL 1	pH Sensor Reading	ORP Sensor Reading
Trial 1		
Trial 2		
Trial 3		

Table 3.16 shows the pH and ORP sensor reading from the controlled inflatable pool setup for three trials.

For controlled and uncontrolled testing:

Null Hypothesis (Ho): There is no significant difference between the controlled setup and the uncontrolled pool setups.

Alternative Hypothesis (Ha): There is significant difference between the controlled setup and the uncontrolled pool setups.

Table 3.17 Comparison of set-ups with respect to pH sensor reading

<table>
<tr><td colspan="5">pH reading Compared to Controlled Setup</td></tr>
<tr><td colspan="5">Number of samples for all N=3</td></tr>
<tr><td colspan="5">pH reading (Controlled) Set-up:
Mean= Max= Min= Standard Deviation=</td></tr>
<tr><td>Set-up</td><td>Mean</td><td>Maximum pH reading</td><td>Minimum pH reading</td><td>Standard Deviation</td></tr>
<tr><td>Pool 1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pool 2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pool 3</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 3.17 shows the statistical analysis of the pH sensor reading of each uncontrolled pool setup in comparison with the controlled inflatable pool set-up. The variation of the pH reading of every setup is analyzed by obtaining the mean, maximum, minimum and standard deviation.

Table 3.18 Comparison of set-ups with respect to ORP sensor reading

ORP reading Compared to Controlled Setup				
Number of samples for all N=3				
ORP reading (Controlled) Set-up: Mean= Max= Min= Standard Deviation=				
Set-up	Mean	Maximum ORP reading	Minimum ORP reading	Standard Deviation
Pool 1				
Pool 2				
Pool 3				

Table 3.18 shows the statistical analysis of the ORP sensor reading of each uncontrolled pool setup in comparison with the controlled inflatable pool set-up. The variation of the ORP reading of every setup is analyzed by obtaining the mean, maximum, minimum and standard deviation

Table 3.19 Comparison of Controlled Setup and the Selected Pool from the Uncontrolled Testing

Parameter	Controlled Setup			Verification Setup from uncontrolled Testing				
	N	Mean	Standard Deviation	N	Mean	Standard Deviation	T test	P value
pH sensor reading								
ORP sensor reading								

In order to verify the results, the parameters for the pool specifically the pH and ORP sensor readings are taken into statistical analysis for verification if there is a significant difference between the controlled pool setup and the uncontrolled pool setups. Table 3.19 shows the statistical data for the controlled pool setup and the Selected Pool from the Uncontrolled Testing.

3.3.6 TFT LCD as an Alert System

The LCD is programmed to display a blinking colored background to alert the user about the adverse effects. The blinking will not stop unless the user touches the screen of the LCD. After the screen is touched, the list of adverse effects and the status of the ORP and Ph level will be shown. The LCD will begin to blink again if the pool parameters have not been regulated to the acceptable range of pH and ORP.

3.3.7 Bluetooth Terminal Application

A Bluetooth terminal will also be used as part of the alert system for pool water monitoring. Same with the TFT LCD, after analyzing and processing the gathered data, the list of possible adverse effects and the status of the ORP and pH level will be shown on the remote device.