Integrated Water Quality Testing Device

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Abstract— In recent days, the most important problem that our society faces is water scarcity. Due to contamination of water bodies, drinking water supply, water for agriculture and healthy fisheries has been severely impaired. Over five millions of people die annually from water borne diseases. It has also lead to contamination of marine ecosystems and decrease in crop yields. Unavailability of easy water quality detector has been a major cause which has led to all above mentioned problems. An autonomous, real time and integrated device is designed to measure physical and chemical properties of water. Designed device uses sensors to detect the quality parameters (pH, temperature, turbidity, conductivity). Sensor outputs are processed by Arduino Uno, which sends parameter values to authenticated user via GSM module. Although there are existing methods to detect quality of water, an integrated device is designed which can be used in all the three fields.

Index Terms—Arduino Uno, Conductivity, GSM module, pH, Temperature, Turbidity.

1 Introduction

WATER quality suggests the synthetic, physical and natural traits of water. It is a measure of the condition of water as for the necessities of biotic creature and in addition to any human need or reason. It is most frequently used by the reference to a set of standards against which compliance can be accessed. Principles are utilized to get water quality identified with wellbeing of biological community, security of human contact and drinking water. A portion of properties are total dissolved and suspended solids, pH, temperature, turbidity, conductivity, ammonia factor, salinity, dissolved oxygen and so forth.

As water is general dissolvable, it absorbs number of debasements in different ways. The particles grabbed by the water infrequently make it more helpful and reasonable for drinking, yet now and again, it might make water absolutely destructive and unfit for drinking reason, farming and fisheries [1].

These issues can be solved by as often as possible checking water bodies, which is by building a system to screen a particular water test and send extricated information to an authenticated user. This paper for the most part focuses on estimation of pH, temperature, turbidity, conductivity, total dissolved solids, total suspended solids, dissolved oxygen, salinity and ammonia factor [2]. Existing frameworks are field particular; in this examination we have extended it to three fields, to be specific drinking water, agriculture and aquaculture.

The World Health Organization (WHO) has set up a few rules for drinking-water quality which are the universal reference point for models setting and drinking water security. The most recent rules drew up by the WHO are those consented to in Geneva, 1993. Most critical parameters amongst these are as follows. Turbidity of drinking water can't be higher than 5.0 Nephelometric Turbidity Units (NTU), ammonia factor ought to be under 2mg/l and pH of drinking water ought to be in the range 6 to 8.5. Dissolved oxygen, total dissolved solids, total hardness and E-coli are other primary parameters.

Agriculture is subjected to a satisfactory water supply of usable quality. Water quality concerns have frequently been ignored in light of the fact that great quality water supplies have been plentiful and promptly accessible. This circumstance is presently changing in numerous zones. Salinity, electrical conductivity and total dissolved and suspended solids are the significant quality parameters. Electrical conductivity and total dissolved solids should be less than 0.7dS/m and 450 mg/l respectively.

Water quality is a basic factor while refined any oceanic life form. Ideal water quality differs by species and must be checked to guarantee development and survival. Water quality parameters that are usually observed in the aquaculture incorporate temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia factor and nitrites. Contingent upon the way of life framework, carbon dioxide, chlorides and salinity may likewise be checked. A few parameters, for example, alkalinity and hardness are genuinely steady, however others like disintegrated oxygen and pH change day by day.

2 Methodology

This framework makes use of four designed sensors (temperature, turbidity, pH, and conductivity), processing module Arduino UNO and a data transmission module GSM SIM900A [3]. Sensors are connected to microcontroller. The sensors capture data in the form of analog signals. The inbuilt ADC in Arduino changes over these analog signals to digital format. The microcontroller processes the obtained data and computes the estimations of different parameters, namely, total dissolved solids, total suspended solids, dissolved oxygen, ammonia factor and salinity utilizing conversion

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formulas. Every parameter has wellbeing limit esteem or edge esteem, which is field particular [4]. Microcontroller compares the detected esteem with pre-stored limits. Further communication is done by GSM module, which sends SMS with water quality parameters onto cellphone. (Fig. 1)

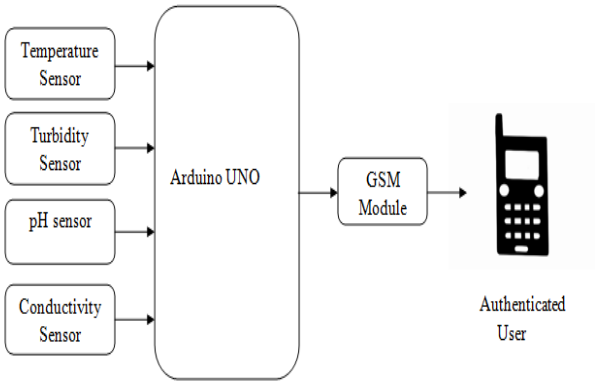


Fig.1. Block diagram of Water Quality Testing Device. It consists of four sensors, microcontroller Arduino Uno and GSM module.

3 Sensor Design and Development

3.1 Temperature Sensor

Fig.2. Temperature senor LM35 made waterproof.

Water temperature is one of the five vital variables of water quality testing. Temperature impacts both the compound and organic attributes of surface water. It controls the rate of metabolic and conceptive processes and consequently oceanic life cycle. Dissolved oxygen level in the water, photosynthesis of aquatic plants, metabolic rates of aquatic organisms and affectability of these organisms to pollution, parasites and disease are the major things influenced by water temperature. If water temperature increases, decreases or fluctuates, these activities may speed up, slow down or stop. Water temperature is usually estimated in Celsius (°C). Design optimization and implementation of air and water quality monitoring systems are challenges for engineers and researchers for many years.

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature, primarily designed for measuring air temperature. Same can be used to measure the temperature of water by following five steps which are used to make it work as a water temperature sensor (Fig. 2) [5].

- Use Cat-5 for the Tether
- Solder the LM35
- Copper Cladding
- Capping the Probe
- Silicon Sealant to Waterproof

3.2 pH Sensor

pH is a decided esteem in light of a characterized scale, like temperature. This implies pH of water isn't a physical parameter that can be estimated as a fixation or in an amount. Rather, it is a figure in the vicinity of 0 and 14 characterizing how acidic or basic water is along a logarithmic scale. The lower the number, the more acidic the watr is. A pH of 7 is viewed as neutral. On the off chance that the pH of water is too high or low, sea-going creatures living inside it will die. pH can likewise influence the solubility and toxicity of the chemicals and substantial metals in the water.

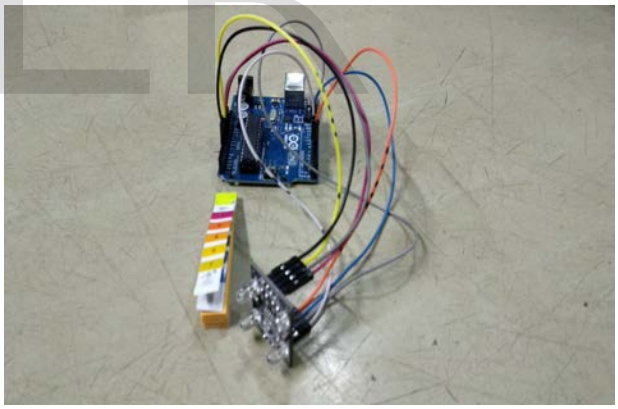


Fig.3. pH sensor constructed using pH indicator paper and color sensor TCS230

pH sensor is constructed using pH indicator paper and color recognition sensor TCS230 (Fig. 3). pH indicator paper is immersed in water and respective color change of the paper is captured using color sensor TCS230. Color sensor is interfaced to microcontroller Arduino Uno. RBG value captured by the sensor is processed using the micro controller and mapped to respective pH value.

3.3 Turbidity Sensor

Turbidity is an optical characteristic of water. It is an expression of the amount of light that is scattered by material in water when a light is shined through the water sample. High groupings of particulate matter influence light infiltration and

efficiency, recreational esteems and quality of natural surroundings. Immoderate turbidity or darkness in drinking water is unappealing and may likewise speak to a health concern.

Turbidity sensor is developed using LED and LDR connected to Arduino Uno (Fig. 4). The Light dependent resistor or LDR acts as the sensor that indicates the cloudiness of water. The setup for cloudiness sensing is by positioning light emitting diode or LED at 90 degrees to the LDR. Made from high resistance semiconductor, LDR is a variable resistor whose value decreases with increasing incident of light intensity [6].

Fig. 5 illustrates the measurement circuit of LDR voltage used to determine the turbidity of water. When the LED illuminates in clear water, the LDR will send low voltage to the analog input of Arduino Uno. In contrary, when murky water flows, the LDR will send Arduino Uno a high voltage instead.

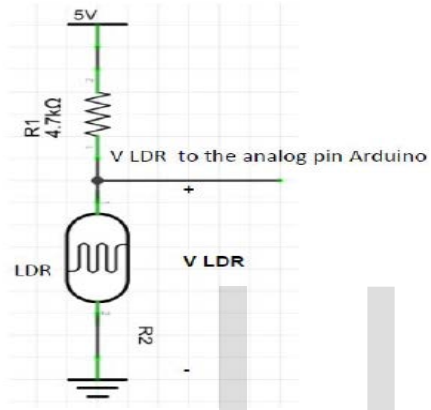


Fig.4. Voltage divider for sensing LDR voltage where Vldr is measured to the analog input of Arduino

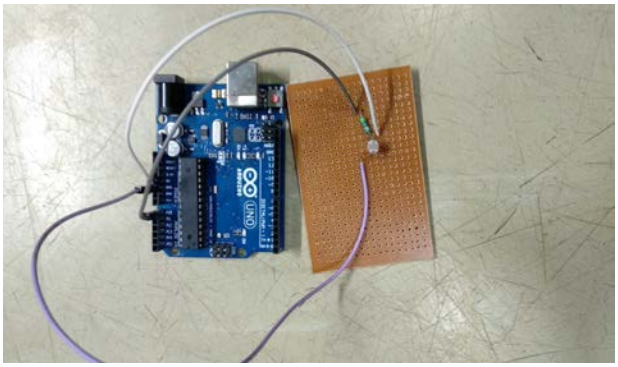


Fig.5. Turbidity Sensor detector module connected to Arduino Uno

Turbidity measurement due to relative light transmission can be defined by the absorbance logarithmic value:

$$Turbidity = \log(Rx / Ro) \quad (1)$$

Rx denotes as the value of resistance when the water becomes murky and Ro is the intial condition of the water. By assuming that current flow is negligible and the value of Vldr in Fig. 5 is propotional with respect to Rx in (1), the measured input voltage into Arduino Uno can be used to calculate turbidity of water.

$$Turbidity = \log(Vldr / Vo) \quad (2)$$

Where Vo is 2.236V.

3.4 Conductivity Sensor

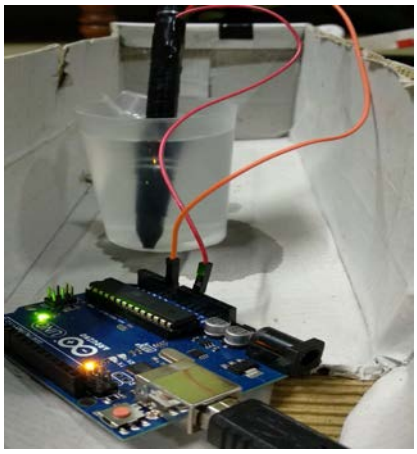


Fig.6. Conductivity Sensor developed using copper wire, nichrome wire and a disposable pen connected to Arduino Uno

Conductivity characterizes the capacity of water to conduct electricity. This kind of estimation gets to the concentration of ions in a solution. Increasingly the ions higher will be the conductivity. On the off chance that conductivity levels are high, particularly due to dissolved salts, numerous types of aquatic life are influenced. Skin of animals is dehydrated due to the presence of salts. High concentrations of dissolved solid can add a laxative effect to water or cause the water to have an unpleasant mineral taste. It is also possible for dissolved ions to affect the pH of water, which in turn may influence the health of aquatic species.

Conductivity sensor is constructed using nichrome and copper wire, both of which act as electrode. Here, copper wire is taken as reference electrode and nichrome wire gives actual conductivity value. A dismantled disposable pen used, behaves as an insulator between the two wires. Both the wires are soldered to an external wire, which is connected to Arduino Uno. Wires are gum taped such that only one centimeter of them is exposed to water sample. Value thus measured gives conductivity of water sample. (Fig. 6)

4 Measurements of other Parameters

4.1 Ammonia factor

Ammonia gets into water supplies most habitually as overflow in farming zones where it is connected as manure and it effortlessly discovers its way into underground aquifers from creature feedlot runoff. Ammonia itself isn't regularly found in well water since microscopic organisms in the dirt change over it to nitrates.

Ammonia can be extremely destructive to some copper plumbing frameworks. It isn't controlled by current drinking water models. It is dangerous to fish and dialysis patients. Its danger shifts with the pH of the water.
The ammonia factor is computed based on pH and temperature using the equation below derived from Millichip. The ammonia factor can be indirectly controlled by controlling the pH and temperature [2].

$$A = [10((0.0901821) + (2729.92/(273.15 - Tc) - pH) + 1]^{-1} \quad (3)$$

Where:
A = Ammonia factor
Tc = Temperature in Celsius
pH = pH reading

4.2 Dissolved Oxygen

Dissolved oxygen concentration is considered the most important quality variable in fish culture. It influences water quality and growth of breeding biology and animals, it is an urgent requirement assignment to predominate the dynamic changing rule of dissolved oxygen and predict the dissolved oxygen in the breeding ponds during aquaculture production.

Value of dissolved oxygen can be calculated from the temperature of water using below mentioned equation [7]:

$$DO = 0.0031090981 \times T^2 - 0.31570264 \times T + 14.165947 \quad (4)$$

Where:
T = Temperature in Celsius
DO = Dissolved oxygen in mg/l

4.3 Total Suspended Solids (TSS)

Total suspended solids (TSS) are both a significant part of physical and aesthetic degradation and a good indicator of other pollutants, particularly nutrients and metals that are carried on the surfaces of sediment in suspension.

A log-linear model shows strong positive correlation between TSS and turbidity with a regression equation [8]:

$$\ln(TSS) = 1.32 \ln(NTU) + 0.15 \quad (5)$$

Where:
TSS = Total suspended solids in mg/l
NTU = Turbidity in NTU

4.4 Total Dissolved Solids (TDS)

Matter present in the dissolved form consists of inorganic salts and organic matter which is represented in the form of Total Dissolved Solids (TDS). The inorganic TDS is contributed predominantly by six major ions such as calcium, magnesium, sodium, bicarbonates, chlorides and sulfates and measured gravimetrically.

Electrical conductivity (EC) is a surrogate measure of Total Dissolved Solids (TDS). The relationship between TDS and EC is a function of type and nature of the dissolved cations and anions in the water. The relationship between EC and TDS is not directly linear, since the conductive mobility of ionic species is variable. In general, the TDS – EC relationship is given by the equation [9]:

$$TDS = 0.64 \times EC \quad (6)$$

Where:
TDS = Total Dissolved Solids in mg/l
EC = Electrical Conductivity in uS/cm
0.64 = Conversion factor for natural water

4.5 Salinity

Salinity is the measure of the considerable number of salts broke up in the water. It is generally estimated in parts per thousand (ppt) or gram per kilogram (g/kg). The normal sea salinity is 35ppt and the normal waterway salinity is 0.5ppt or less. This implies in each kilogram (1000grams) of sea water, 35 grams are salt. Since the water in estuaries is a blend of crisp water and sea water, the salinity in many estuaries is not as much as the vast sea. Base water quite often contains more salt than surface water.

The relationship between conductivity (X) and salinity (S) was investigated in 109 samples from Australian salt lakes. Within the range of 5-100 mS/cm, the relationship is described by the equation [10]:

$$S = 0.4665 \times 1.0878 \quad (7)$$

Where salinity is measured in g/kg and conductivity is measured in mS/cm at 25oC.

5 Results

Water quality of well water was tested using the device. Outputs were seen on both smartphone and computer (Arduino Serial Monitor) (Fig.7 and Fig.8). Same sample was tested using existing chemical and other practiced methods. It was seen that output of the device had +/-5% error, which did not make huge difference in practical scenario.

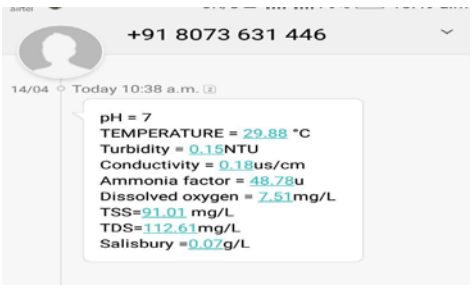
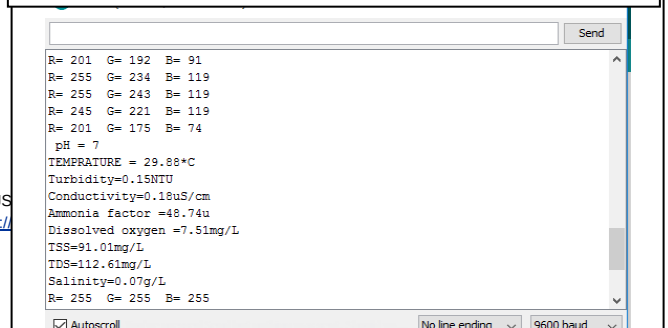


Fig.7. Results for water as seen on the smart phone



6 Conclusion

In this paper, a water quality testing device was proposed which could be used in all the three fields, namely drinking purpose, agriculture and aquaculture. Designed device was low cost as it used hardware for measuring four water quality parameters (temperature, pH, turbidity, conductivity) and using those outputs, value of five other parameters (ammonia factor, dissolved oxygen, total suspended solids, total dissolved solids, salinity) were calculated using mathematical relationships.

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