Water Sampling Device

Overview

Tank Water Sampler:

A device that is connected to a water source such as a tank. That can sample the water and determine if the water is safe to drink. In real time. The sampler will upload data to a website which will notify the user if the water quality has diminished.

Motivation

The motivation is to help people have the knowledge that they are drinking water from a safe water source. In the year 2000, the World Health Organisation found that 2.2 million people died from diarrheal diseases from poor water sources. (Gleick, 2002).

With all these deaths that can be prevented, a device that can quickly scan the water and make an estimate on the water quality, is a good first line of defence to determine if the water is safe to drink, or if follow up action is needed.

Description

Water testing module– The module will comprise a compact, inline, and weatherproof device connected to a throughput from the water source i.e., Tank, well, dam or river via a pump etc. To test for, detect and provide live alerts on the general parameters of the water in a qualitative manner. Frequency of testing has been an issue with more frequent testing given to unknown or lesser understood water sources. This module will remove the challenges associated with this by constantly updating the baseline values and flagging indicators of water quality issues such as the following;

Colour and Turbidity – The water sampler will give optics on the presence of pathogens in the water which have not been filtered out by the filtration media. While colour and turbidity are primarily aesthetic considerations, providing real time coverage of this property will provide two benefits to the consumer. Deterioration may indicate changes in the characteristics of the water source or signal reduction in efficacy of filtering systems, with resulting changes in taste and potential water quality. Turbidity and colour are also indicative of the volume of undissolved solids present in the water source, which can provide vectors for harmful pathogens.

Temp - Certain temperatures ranges can foreshadow potential increases in the amount biological pathogens present in the water.

Electrical conductivity - Electrical conductivity is used as an indicator of total dissolved solids present in the water source. While this parameter does not differentiate between the types of elements or other water-soluble compounds in the water it gives a crude gauge of potential salinity and provides a baseline for ongoing monitoring.

PH (Acidity/Alkalinity) - This will affect the amount and type of bacteria as well as the ability for other organic material to grow in the water.

Data Capture, UI (User Interface) – These parameters will be used to develop a broad overview of the water quality by comparing with reference and baseline values. This overview will be presented to the consumer through an intuitive interface, allowing rapid assessment of the current state of the water source.

Description Summary - This device will provide household consumers with a cost-effective solution to high level monitoring of their water quality. This device does not intend to replace conventional water quality testing or municipal level sampling practices, it is targeted at market segments which previously did not have access to a low-cost solution such as rural households, remote communities, and other high risk low volume consumers. If the device detects a notable change in measured values, the user will be prompted to initiate additional and more extensive conventional testing methods.

According to Australian water guidelines (222032 NHMRC (National Health and Medical Research Council) ADWG 6_Version 3.7 FF2032 NHMRC ADWG) Waterborne microbial pathogens are the single most important contaminants to test for and remove from a drinking water source. This is comprised of Viruses, parasites, and bacteria. While this device will not give quantitative measurements of these contaminants it will indicate conditions conducive to their presence.

Tools and Technologies

To achieve the goals defined above, it is proposed to fabricate an in-line device which contains sensors applicable to the quality parameters that have been selected. This will be coupled with a microprocessor to receive the raw sensor data, apply any calibrations required, and output the compiled data to a human interface.

For colour and turbidity sensing, the TCS3200 integrated colour sensor (TAOS Inc, 2009) was considered and rejected due to its limited resolution. To achieve the resolution required, a LED light source of known characteristics with be coupled with a low resolution (2-4mp) camera module within the sampling device housing to capture images. and the average RGB values calculated for the entire frame. No minimum required colour parameters were able to be identified while researching, so the acceptable limits of colour will be chosen arbitrarily and adjusted based on feedback from field testing. Measurement of turbidity will also be achieved, by calculating the attenuation of the light intensity through the test medium. This value will be normalised to the Nephelometric Turbidity Units (NTU) scale, with an upper limit set at 0.5 NTU as per the guidelines (National Health and Medical Research Council, 2011).

A DS18B20 sensor will be utilised to sample the water temperature. This sensor is available in a sealed submersible configuration and has a range of -10°C to +85°C with a 9-bit resolution that equates to 0.5°C per step (Dallas Semiconductor, n.d.) which far exceeds the requirements for this application. The single wire output of the sensor will be coupled to an analogue input on the host microcontroller.

The electrical conductivity of the sample medium will be measured with the value being indicative of the salinity and dissolved mineral content (Corrosion Doctors, 2022). A pair of electrodes mounted within the sample vessel will form one resistive element of a basic voltage divider circuit. By applying a voltage (V_{in}) through the circuit, with a known resistive value at R_1 and the sample medium acting as R_2, a voltage can be measured across V_{out}. Comparing the sampled voltage to the input voltage, the resistive value of the sample medium (R_2) can be calculated.

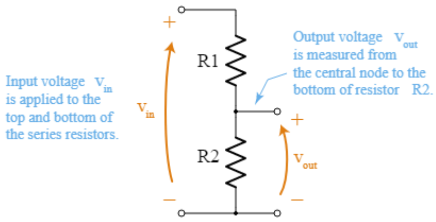

Fig. 1

Fig. 2

$$v_{out} = \left(v_{in} \frac{1}{\mathrm{R1} + \mathrm{R2}} \right) \mathrm{R2}$$

(Kahn Academy, 2022)

The conductivity measurements can then be compared to published values and an approximation of the salinity and mineral content made.

Water type	Ω (ohm per cm)	Voltage divider (volts)
Pure water	20000000	

Distilled water	500000	0.192
Rainwater	20000	2.5
Tap water	1000-5000	4.762 - 4
River water (brackish)	200	4.95
Seawater (costal)	30	4.993
Seawater (open sea)	20-25	

(Corrosion Doctors, 2022)

The output of this sensor will be indicative only, as the exact composition of the water and the effect this has on conductivity will not be known. While inherently inaccurate, this will allow the device to signal that the sample medium has exceeded normal ranges and more precise quality testing is required.

A generic prebuilt Ph (Acidity/ Alkalinity) module will be utilised for the initial prototype (e-Gizmo, n.d.). While researching these modules, a formal datasheet was unable to be found. These devices are based on measuring the voltage potential difference (current) between a reference electrode and an electrode sensitive to ionised hydrogen (Bijekar, 2022). A dedicated signal conditioning circuit takes the sensor current and outputs an analogue voltage which directly correlates to the Ph of the sampled medium.

For the prototyping phase, the physical components will be built on the Arduino platform (Ardunio.cc, 2022). The Arduino Uno provides an 8bit microcontroller integrated into a circuit with all the components required to form a fully functional single board computer. The temperature, electrical conductivity and PH sensors output an analogue signal which will be converted to digital signal through one of the six 10-bit analogue to digital converter (ADC) inputs available.

The optical sensor (camera) data will also be passed through the Arduino platform. It is hoped that this signal can be processed to output RGB values for colour and turbidity measurements directly onboard. If this is not possible, the raw images will be passed to another device for processing.

A program to read the sample data and output a structured data feed will be flashed onto the microprocessor which forms the core of the Arduino Uno. Arduino provide a software package for developing, compiling, and interfacing with compatible boards, known as the Arduino IDE (Integrated Development Environment) (Arduino.cc, 2021). The IDE includes a text editor for writing code, utilising a modified version of the C++ programming language.

The specific hardware utilised in the initial prototype is subject to change based on the availability of components and functionality observed during testing.

Skills Required

This project will require a wide variety of skills to produce a proof of concept. These include physical fabrication of the sampling vessel, circuit construction, low level (close to hardware) and high level (human interface/ GUI (Graphical User Interface)) programming skills.

Analysis of the physical characteristics of the materials chosen for fabricating the sampling vessel will determine the construction method and final form of the vessel.

The design of sensor and other related circuitry necessitates an ability to locate and comprehend the technical literature associated with the components selected. These components will be tested to confirm suitability for the intended application and alternatives chosen if required.

To produce the software which will be flashed to the Arduino board (known as a sketch), members will need to become familiar with the Arduino IDE environment, the specifics of the AT Mega microcontroller and concepts required to produce functional programs in the C++ language. An intimate understanding of the interaction between software and hardware will need to be achieved to enable developers to effectively utilise the functionality of the Arduino platform required to read and process the sensor signals. There is a wealth of knowledge available through the open-source community to assist in this.

Depending on the human interface method chosen, a PC (Personal Computers) application or interactive webserver may need to be developed requiring skills with development tools which are applicable. As development progresses, the team will decide on the most effective interface technology. There are currently three high level options.

1. An LCD screen or other visual output device directly integrated into the Arduino platform.
    - This option would provide a simple but effective method to output sampling data to the user.
    - Would require extensive development of the Arduino sketch to produce a structured and formatted output.
    - By nature, this would need to be mounted directly to the device, exposing the screen to the environment it is mounted in and requiring the target recipient physically access the device.
2. A PC interface via USB, Ethernet, or Wi-Fi connection
    - This choice provides physically remote access to the data being output by the device.
    - Would require configuration of the Arduino to output a suitable data stream and an interface process between the Arduino and the PC.
    - May require additional hardware to connect with protocol unsupported by the Arduino platform natively (Ethernet and Wi-Fi)
    - Would require client-side application development to ingest and display the device data. There are several languages suitable for this task, one of which will be decided on based on the functional requirements.
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3. A web server running directly on the Arduino, on a dedicated device or on a local PC

- This option is the most useful, as it would provide consumers access to the data stream from any device with connectivity to the network or internet depending on how the server is configured.
- Due to the limited computational capacity of the Arduino device, a dedicated web server is likely to be required to absorb the demand. This would need to be developed. There are several options for deploying a web server, from another Arduino dedicated to the purpose, Raspberry Pi devices as well as more traditional PC and server-based options.

Following proof of concept, an iterative design process will further integrate the required circuits. It is proposed a final product would replace modular sensor conditioning circuitry and the Arduino platform by embedding on a single board. The human interface component will also require further development to produce a fast, intuitive, and functional process to display information to consumers.

Outcome

The aim of the water sampling unit is a prototype that can sample water from a flowing water source, giving a live water quality indication. Notifying consumers that the water at that present moment is safe to drink.

The minimum outcome is a working prototype of the water sampling unit, that can give a reading from a water source. This needs to be accessible on a user interface displaying the current water quality readings.

Predicted issues include calibration of the sensors to ascertain a baseline of values concurrent with safe ranges for drinking water and to accurately monitor and sample a flowing water source.

The impact of a working unit has enormous potential to empower consumers to accurately determine if water is safe to drink or if there are indications of a potential issue.

References: Motivation

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References: Description

Australian Drinking Water Guidelines (nhmrc.gov.au) chapter 6 page 79

Going to sample 'Colour/ Turbidity/ Temperature/ Electrical Conductivity/ PH (Acidity)

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