2.1 Literature Survey

2.1.1 Theory Associated With Problem Area

In order to calculate water quality, the indices generally used for the same were investigated.

Indices used in water quality.

**1.** **Chemical oxygen demand (COD):** This is the equivalent amount of oxygen consumed (measured in mg/l) in the chemical oxidation of all organic and oxidisable inorganic matter contained in a water sample.

**2.** **Biochemical oxygen demand (BOD):** This is the oxygen requirement of all the organic content in water during the stabilisation of organic matter usually over a 3 or 5 day.

**3.** **pH**: This is the measure of the acidity or alkalinity of water. It is neutral (at 7) for clean water and ranges from 1 to 14.

**4.** **Dissolved oxygen (DO):** This is the amount of oxygen dissolved in a water sample (measured in mg/l).

**5.** **Turbidity:** This is the scattering of light in water caused by the presence of suspended solids. It can also be referred to as the extent of cloudiness in water measured in nephelometric turbidity units (NTU).

**6.** **Electrical conductivity (EC):** This is the amount of electricity that can flow through water (measured in Siemens), and it is used to determine the extent of soluble salts in the water. 248 J. O. Ighalo et al.

**7.** **Temperature:** The is the degree of hotness or coldness of the water and usually measured in degrees Celsius (°C) or Kelvin (K).

**8.** **Oxidation-reduction potential (ORP):** This is the potential required to transfer electrons from the oxidant to the reductant, and it is used as a qualitative measure of the state of oxidation in water.

**9.** **Salinity:** This is the salt content of the water (measured in parts per million).

**10.** **Total Nitrogen (TN):** This is the total amount of nitrogen in the water (in mg/l) and is a measure of its potential to sustain and eutrophication or algal bloom.

**11.** **Total phosphorus (TP):** This is the total amount of phosphorus in the water (in mg/l) and is a measure of its potential to sustain and eutrophication or algal bloom

2.1.2 Existing Systems and Solutions

Similar to the theory above, two main water analyzer products were explored.

1. SWA1 – Smart Water Analyzer, a highly sensitive, affordable spectrum sensor for continuous online monitoring and rapid detection of microbial contamination in water.

The water from the water source pipe is passed into the SWA-1 sensor, and flows through the sensor’s inner channel. Two LED sources are installed at one end of the channel and emit light at various wavelengths, 260-300 nm and 750-900 nm respectively. A special sensitive receiver is installed at the opposite end of the channel. Emitted light beams pass through the water medium in the channel and encounter particles of various origin. As a result, light energy is absorbed by the particles, and the receiver identifies reduction in the energy power, as compared to that measured when the “baseline” water quality reference was established (which may be referred to as a “reference light energy” level).

to obtain reliable data on the microbial contamination load in water, an additional LED source is used in the sensor’s channel that emits light at wavelengths in the range of 750-900 nm. Under such radiation wavelengths, light energy is absorbed by particles of non-biological origin. SWA-1 compares measurement results at various light wavelength ranges, and if certain ratios between signal strength levels at various UV and IR wavelengths are reached, the sensor provides an indication whether the contamination is microbiological or general.

The SWA1 sensor sensitivity starts at 10 bacteria in 1 milliliter of source water. Such high sensitivity is attained by a proprietary algorithm of the water source irradiation by light sources. The unique light radiation algorithm and self-cleaning ability  constitute the principal IP claimed in Fluidsens patent applications.

2. VWM Solutions

ColiMinder technology is based on direct measurement of specific metabolic (enzymatic) activity of target organisms present in the sample. The enzymatic approach directly measures the specific enzymatic activity present in the sample. The measured enzymatic activity per sample volume is used as a measure of the contamination.

The enzymatic measurement approach is the only rapid measurement approach that allows:

->Technology independent determination if contamination limits

->Calibration of devices independent of their measurement technology

The enzymatic approach evaluates the level of contamination by measuring a signal from all target organisms in the sample volume. This approach requires no sample pre-treatment and less sophisticated technology and is therefore more robust than approaches evaluating individual organisms.

There are enzymes that are specific to certain organisms or groups of organisms. This offers the possibility to specifically measure the metabolic activity of the respective target organisms.The most basic indication of a viable organism is its metabolism, since it reflects the energy that the cell takes from the environment. This metabolism takes place through enzymes.The metric is the enzymatic activity per volume of a specific enzyme. It reflects the energetic turnover of the target organisms per volume or in other words the concentration of living target organisms, which represents the degree of contamination.

KEY FEATURES:

->fully automated sampling, measurement, cleaning and calibration

->Online data visualization and automatic notification

->1000 measurements without staff intervention

->up to 54 (80 in special cases) measurements per day

->Fully controllable through internet connection

->2 sample intakes (more optional)

DATA TRANSFER AND VISUALIZATION:

->Measurements data is directly transmitted to server through internet/ network connection

->Live data visualization on dedicated website, results can be downloaded

->Automatic notifications can be set (E-mail, SMS)

->Measurement results are also available through RS232/RS485 or Modbus TCP (optional)

->Measurement results can be saved on USB Flash Drive directly from the device

->4 to 20 mA output optional

2.1.3 Research Findings for Existing Literature

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| **S.** | **Roll** | **Name** | **Paper Title** | **Tools/** | **Findings** | **Citation** |
| **No.** | **Number** | **Technology** |
| 1 | 101983043 | Umang Sharma | Surface Water Pollution Detection using Internet of Things,  Shafi et al. | Investigated the surface water across 11 locations in Pakistan by  monitoring pH, turbidity and temperature. The algorithms considered were Support Vector Machine (SVM), k Nearest Neighbour (kNN), single-layer neural network and deep neural network. | It was observed from the learning process on the 667 lines of data that deep neural network had the highest accuracy (at about 93%). The model could accurately predict water quality in the future six months. | Shafi, Uferah & Mumtaz, Rafia & Anwar, Hirra & Qamar, Ali & Khurshid, Hamza. (2018). Surface Water Pollution Detection using Internet of Things. 92-96. 10.1109/HONET.2018.8551341. |
| 2 |  | Application of Environmental Internet of Things on water quality management of urban scenic river,  Wang et al | Chemical analysis of water was done by monitoring COD, pH, Turbidity, Temperature, Salinity, ORP.  COD was measured by a Hach analyzer DR5000.  The concentrations of NH4+-N, NO2−N,NO3−N, total phosphorus (TP), and total nitrogen (TN)were measured according to the standard method (MEPC2002b) | Their system was divided into three subsystems-  Data acquisition, Digital data and Data processing | Wang, Shumei & Zhang, Zhaoji & Ye, Zhi-Long & Wang, Xiaojun & Lin, Xiangyu & Chen, Shaohua. (2013). Application of Environmental Internet of Things on water quality management of urban scenic river. The International Journal of Sustainable Development and World Ecology. 20. 10.1080/13504509.2013.785040. |
| 3 |  | Real-time water quality monitoring using Internet of Things in SCADA,  Saravanan et al | Monitored the turbidity, temperature and colour using technology that was usable in real-time and employed a GSM module for wireless data transfer | Proposed a new SCADA system that integrates with the IoT technology for real-time water quality monitoring. Physical parameter such as temperature, turbidity, and color were added to the system. This real-time application generates, collects, transfers, and stores sensor data in the web server by using the GSM module. | Saravanan, K., Anusuya, E., Kumar, R. et al. Real-time water quality monitoring using Internet of Things in SCADA. Environ Monit Assess 190, 556 (2018). https://doi.org/10.1007/s10661-018-6914-x |
| 4 |  | Analysis and prediction of water quality using LSTM deep neural networks in IoT environment | Temperature, pH, DO, Conductivity, Turbidity, COD and NH3 were monitored using IoT enabled devices which incorporated a Long Short-Term Memory (LSTM) deep learning neural network. | The results of the study indicate that the predicted values of the model and the actual values were in good agreement and accurately revealed the future developing trend of water quality, showing the feasibility and effectiveness of using LSTM deep neural networks to predict the quality of drinking water. | Liu, P. & Wang, J. & Sangaiah, A.K. & Xie, Y. & Yin, X.. (2019). Analysis and prediction of water quality using LSTM deep neural networks in IoT environment. Sustainability (Switzerland). 11. 10.3390/su1102058. |
| 5 |  | Real-time water quality system in internet of things,  Zin et al. | pH, turbidity, temperature, water level and carbon dioxide monitored using wireless sensor network enabled by IoT  system consisting of Zigbee wireless communication protocol, Field Programmable Gate Array (FPGA) and a personal computer. | The results of the proposed system were validated with the laboratory  experiments. Based on the results, it can be concluded that there was no significant difference  of water data measurement between the proposed system and the laboratory measurement. The  proposed WQM system was able to minimise the operating time, cost and power consumption | M Cho Zin et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 495 012021 |
| 6 |  | GIS-based assessment of groundwater quality for drinking and irrigation purposes in central Iraq | The analysed water quality parameters were used as an attribute database to produce thematic maps using a geographical information system (GIS) environment.  the water quality index (WQI) and the irrigation water quality index (IWQI) were calculated for different groundwater samples using various parameters including the Electrical Conductivity (EC), Cl−, HCO3−, Na+ and pH. Moreover, the groundwater suitability for irrigation purposes has been assessed using indices such as Kelly’s ratio (KR), sodium absorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP) and permeability index (PI). | The SAR ratio obtained from the samples indicates a medium to high sodium concentration, which is appropriate for irrigation but not ideal. Also, SSP values showed that 30% of the water samples tested are not safe for irrigation. Meanwhile, the permeability index (PI) results showed that water quality in the study area is appropriate for irrigation use. | Makki, Z.F., Zuhaira, A.A., Al-Jubouri, S.M. *et al.* GIS-based assessment of groundwater quality for drinking and irrigation purposes in central Iraq. *Environ Monit Assess* **193,**107 (2021). https://doi.org/10.1007/s10661-021-08858-w |

2.1.4 Problem Identified

The biggest issue that was seen whilst exploring previous methods of water quality assessments was that the data collection and data analysis for assessing the water quality were not being done in an automated manner. Whilst some used machine learning methods such as SVM, kNN to classify water, it was not being done on-site. In most cases the data was being collected, uploaded to a computer for analysis using computationally expensive machine learning algorithms like the ones mentioned above. This will be detrimental to a farmer who may not have 24/7 access to the internet.

This brings us to the second point that there has not been enough research regarding simpler classification techniques. K nearest neighbours requires constant calculation and sorting. Deep learning neural networks require a lot of memory based on the transformers used. We believe that carefully selected features along with using a simpler classification technique will work just as well, if not better than the ones already being used.

2.1.5 Survey of Tools and Technologies Used