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Water Quality Sensors: Need or Demand

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Global life may have a carbon basis, but water makes up the majority of its mass. For the maintenance of life in all of its elements, access to clean water is crucial. The stress on our planet's valuable resources especially water has significantly increased, primarily as a result of human activity, necessitating action in water management and purification. In order to quantify the issue and assess how well corrective measures are working, water quality sensors are required. The most prevalent chemical water quality criteria are included together with the most recent advancements in sensor technology that can be used to monitor them. Technology that supports reagent-free, low-maintenance, autonomous, and continuous monitoring is given special attention. Mechanical, optical, and electrochemical sensors are also mentioned, along with chemi-resistors and other electrical sensors. Here, the emphasis is on the mechanics of chemical signal transduction in sensor components in close proximity to the analyte. Other sensing techniques, components of sampling, sample pre-treatment, data collection, transmission, and analysis are not included in this article. For an audience of physicists and materials scientists, the objective is instead to highlight the advancement and enduring difficulties in the development of water quality sensors and designs. In addition, the author would like to mention the need and demand of the same with special emphasis.

Keywords: Design, Chemi-resistors, Purification, Quality, Sensors and Water.

Introduction

All civilisations have understood the fundamental significance of water for life, long before our modern western knowledge base. Even though there is a lot of water on this globe, surface water contamination is an increasing issue, and only one-sixth of the world's population has access to clean drinking water. As a result, environmental laws have been passed in many nations to cut pollution, and work is being done to create reliable technologies for drinking water purification in distant and resource-limited areas. In compliance with the water framework regulation and national water legislation, surface water in every country or nation is uninterruptedly monitored by public authorities through permanent monitoring stations. Additionally, water companies keep an eye on drinking and waste water as well as surface or ground water close to the input of the drinking water treatment plant. Sensors assist in some of the monitoring, although they only measure the most fundamental physicochemical variables, such as flow rate, turbidity, pH, temperature, conductivity, and pressure. Other metrics, like as chlorine, fluoride, nitrate, particle count, or total organic carbon, can also be monitored online depending on the unique needs of each site. As a result, environmental laws have been passed in many nations to decrease pollution, and work is being done to create reliable technologies for drinking water purification in distant and resource-limited areas. Water quality sensors are a significant growing application of sensor technology in this area. Due to easier experimental design for sensor characterization and better environmental control, gas sensing has historically been the emphasis of sensor materials development.

On the other hand, biosensors have undergone extensive development and are frequently grounded in rather empirical research since they serve significant societal and commercial demands. For ensuring access to clean water in urban and rural areas, water quality sensors are crucial. Additionally, they can be utilised for environmental management in the agriculture, military establishments, industrial and municipal waste water treatment, and resource extraction industries. Automated, remote, and in-person monitoring of mining tailing pond runoff, industrial process water (including oil sands), municipal and industrial waste water, agricultural irrigation, and drainage could result in immediate notification and prompt corrective action that could prevent significant environmental harm. Drinking and surface water quality parameters, including the use of disinfectants, are covered by a variety of international and national norms. It can be difficult to maintain recommended or statutory limitations. Because they are either single-use, need reagents, or require specialised skills for operation or maintenance, the majority of current sensing technologies are laboratory based and not appropriate for continuous sampling in a remote context. All of these factors greatly raise the cost of environmental monitoring. The most frequent methods for monitoring pollutants and disinfectants are colorimetry, electrochemistry, and lab-based spectroscopy. Colorimetric techniques often involve manual, discontinuous testing and have a limited degree of accuracy. Spectroscopic techniques need extra chemicals and complicated equipment, which makes ongoing field observation or even automated sensing very difficult. The flow rate and ageing of the electrodes (particularly the reference electrode) have a significant impact on electrochemical procedures, making frequent calibration necessary. ChemFETs and chemiresistors have mostly been researched for gas sensing but are increasingly also being developed for applications of water quality. This study begins with a synopsis of the specifications for measuring the quality of the water before outlining the design features of a chemical sensor for liquid analytes. Finally, the major sensing technologies (mechanical, optical, electrochemical, and electrical) are covered in relation to their successful present and previous use in water quality sensing. There is no discussion of strictly laboratory-based techniques, physical property sensors, biosensors, sampling techniques, or sample pre-treatment techniques. There is remote sensing technology that uses spectrometric techniques based on satellite, aircraft, or drones. Such techniques can swiftly collect a lot of data from a wide area of the earth's surface, but they eventually need to be calibrated against ground-based techniques and are unable to accurately capture all characteristics.

Water Quality Parameters

Although there are many different parameters that can be used to describe the quality of water, depending on the application, just a few important parameters are frequently observed. Surface waters (oceans, harbours, streams, lakes) as well as groundwater, agricultural irrigation runoff, industrial or municipal waste water, industrial process water, cooling water in power plants or industry, and water in artificial environments like swimming pool. Physical, chemical, and biological characteristics must all be taken into account in order to adequately characterise water quality.

Chemical Sensors

A chemical sensor is generally understood to be a tool that may reveal details about the chemical make-up of an analyte. This occurs in two steps: (a) identification of a specific chemical characteristic of the analyte, and (b) conversion into a quantifiable physical signal. Chemical sensing involves the following stages, which take different forms:

Analyte conditioning (pre-concentration, separation, and ambient parameter control) is the first step. The second step is identifying or detecting the desired chemical property. In step 3, the chemical signal is (proportionally) converted into a form that may be measured more precisely (electrical, optical, mechanical, etc.). After that, the signal is quantified. Interpretation of the signal or signals, chemometric analysis, multi-parameter analysis, etc.

A number of parameters are commonly quoted to discuss the performance of a sensor:

a. selectivity (between similar analytes) & interference (of other environmental parameters)

b. accuracy & precision (repeatability, resolution)

c. limit of detection & dynamic range

d. resettability / reusability

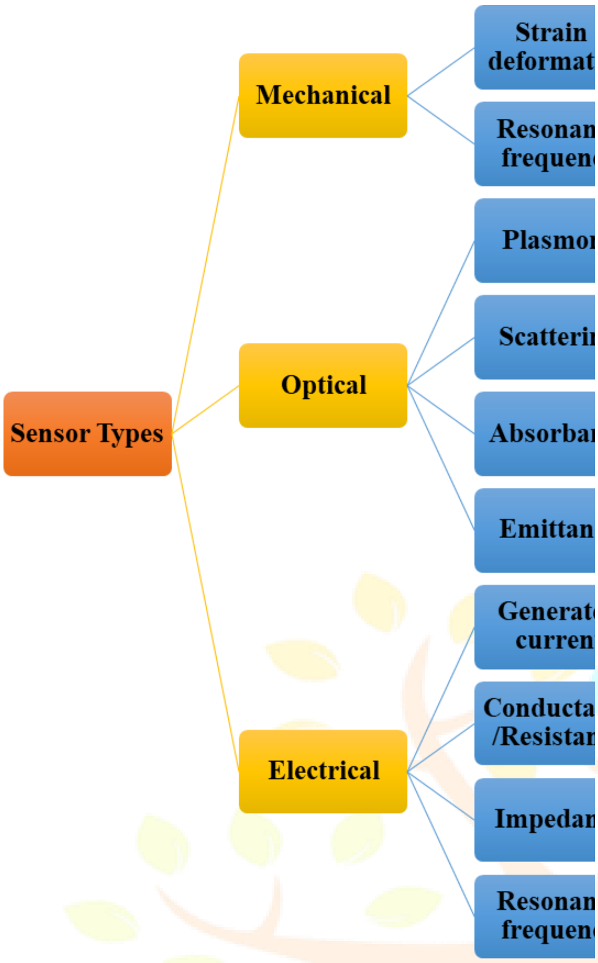

Figure 1. Classification of sensor types based upon the different methods.

Response time, drift/calibration problems, lifespan, and maintenance intervals, and operational range (with respect to environmental parameters) and robustness to abuse, overdose, unfavourable conditions, and operator error

Power usage and autonomy (manual interference, necessary supply)

Sophisticated sensing procedures, signal conditioning, and data processing techniques, including chemometrics, can make up for many of the physical sensing devices' inadequacies (such as drift or selectivity). The limit of detection and dynamic range of a sensor device can both be increased through sample pre-treatment. The geometry of a sensor's receptor portion's interaction with an analyte is a crucial factor to take into account while designing it. The three most popular geometries for sensors are flow, dip, and drop. A certain volume is diverted into a sample container by some sensors to operate.

Some sensors also work by directing a specific volume into a sample compartment and performing the measurement using a static sample (i.e., flow = 0), but with a shape identical to the flow sensor.

The main factors influencing sensor lifetime in aquatic environments are sensor deterioration and biofouling. As will be covered separately in the following sections, deterioration is a problem that is unique to each sensor design and also depends on the detecting mechanism. Because it only happens when the sensor is operating, sensor arrays with redundant parts may be an option. This is because miniaturised sensing elements can be made at a low cost.

Biofouling is the unintentional deposition and formation of a biofilm that includes organic and inorganic matter, bacteria, algae, and other microorganisms. Typically, it begins with the attachment of proteins, humic acid, or other small bioactive molecules. These molecules then promote the growth of microorganisms that eventually form large colonies that may partially separate from the growth surface and clog even those parts of the device that were initially resistant to biofilm growth. Even in the absence of biological or organic stuff, inorganic salts may precipitate and create scale deposits in hard water. Such biological, organic, or inorganic deposits will accumulate even while the sensor is not in use and are likely to interfere with sensor functionality.

Biofouling has an impact on all types of sensors because it prevents optical access, fouls electrodes, and limits physical access to the analyte for the sensor's receptor components.

Therefore, the sensor surface must either be physically or chemically designed to be resistant to biofilm formation and scale buildup, or a maintenance regime must be implemented for film removal. This regime may include mechanical removal, irradiation, ultrasonic treatment, chemical rinses, or application of an electrical potential that either disfavours film buildup or electrochemically triggers pH (or other) changes that lead to film dissolution. Due to Cu2+ being harmful to microbes, copper-based treatments are among of the most widely used commercial antifouling solutions. However, copper itself can be an unwelcome contaminant in high concentrations.

Copper-based products (due to Cu2+ being harmful to microbes, but copper itself can be an undesirable contaminant in high concentrations) and plastic sleeves are some of the most popular commercially available antifouling solutions. Although still in research, antifouling membranes and fouling-resistant surface micro- and nano-structures have not yet achieved commercial success.

Applications

Sensors for measuring water quality have been used to measure and analyse characteristics like pH, turbidity, and conductivity. A single multiparameter controller can incorporate and monitor the commercially available water quality sensors that are currently on the market. The pipeline conductivity, oxidation-reduction potential (ORP), pH, temperature, turbidity, and water flow can all be detected by the system's six in-line sensors. The central measurement node, control node, and notification node make up the three main subsystems that make up the proposed sensor network's overall system structure.

A PIC32 MCU-based board is utilised in the first subsystem to integrate several sensors and gather their data prior to transmission to the remaining nodes. The notification node with connected Zigbee RF transceiver is in charge of notifying users via sms when the sensors detect a sudden change in the concentration of water contaminants. The control node, which is implemented by ARM/ Linux web-server based platform, was used to store the measurement data that is received from central measurement node. To warn users when they are near a water-contaminated region, a local indicator such a buzzer, LCD, or LED was also used as a local near-tap notice. The new hardware's performance was then verified and assessed by injecting E at varied concentrations. The sensors were able to identify concentrations of 0.05, 0.5, 5, 5,000, 50,000, and 50,000,000 CFU/mL when measuring E.

coli, however they were unable to detect low amounts of 5 and 10 g/L while measuring As, according to the results. At concentrations of 25, 50, and 125 g/L, the pH and ORP sensors then responded to the As, whereas at 500 and 1,000 g/L, all the sensors responded well. The water quality sensor has certain restrictions since some contaminants might not be picked up because of the sensor's low sensitivity at low concentrations and the availability of new kinds of developing contaminants. Additionally, the lengthy transmission lags and sluggish response times of The results may also differ when there are variations in the pollutants' concentration, and the sensor was unable to respond immediately to this situation due to the lengthy transmission delays and slow data capture response times.

Conclusion

A variety of chemical sensors based on various detection principles were introduced after discussing pertinent water quality factors. While some factors (like pH) can be quickly and accurately measured using reliable online techniques, other significant quantities are more difficult to quantify. Each type of detection has advantages and disadvantages. Optical sensors can be simple to use manually and have even been developed for remote sensing in some circumstances, however they often depend on the addition of reagents, which necessitates off-line sampling and is frequently done by hand. In order to address this issue, flow-injection analysis techniques have been developed, however they still use reagents. The weakest point for long-term performance of electrochemical sensors is the reference electrode used. The reference electrode used determines how good an electrochemical sensor will always be, and this is where they are most vulnerable to failure over time. Electrical sensors are highly developed for gas sensing, however they frequently lack resilience for liquid environments and are still underdeveloped for many liquid-phase analytes. The community is becoming more conscious of the value of monitoring water quality, and several new procedures are in the works. Technology and data processing techniques are being developed concurrently for the setup of sensor networks, as well as for the thorough analysis and use of the collected data.

References

1. Addisie, Meseret B. "Evaluating Drinking Water Quality Using Water Quality Parameters and Esthetic Attributes." *Air, Soil and Water Research* 15 (2022): 11786221221075005.
2. Arndt, Julia, Julia S. Kirchner, Kevin S. Jewell, Michael P. Schluesener, Arne Wick, Thomas A. Ternes, and Lars Duester. "Making waves: Time for chemical surface water quality monitoring to catch up with its technical potential." *Water Research* 213 (2022): 118168.
3. Cho, Gookbin, Sawsen Azzouzi, Gaël Zucchi, and Bérengère Lebental. "Electrical and

electrochemical sensors based on carbon nanotubes for the monitoring of chemicals in water—A review." *Sensors* 22, no. 1 (2022): 218.

4. Heo, Jun Hyuk, Minchul Sung, Tran Quang Trung, Yullim Lee, Do Hyeon Jung, Hajeong Kim, Sandeep Kaushal et al. "Sensor design strategy for environmental and biological monitoring." *EcoMat* (2023): e12332Hsu, Leo Huan-Hsuan, Aditya Aryasomayajula, and Ponnambalam R. Selvaganapathy. "A review of sensing systems and their need for environmental water monitoring." *Critical Reviews™ in Biomedical Engineering* 44, no. 5 (2016).
5. Mohseni, Farzane, Fatemeh Saba, S. Mohammad Mirmazloumi, Meisam Amani, Mehdi Mokhtarzade, Sadegh Jamali, and Sahel Mahdavi. "Ocean water quality monitoring using remote sensing techniques: A review." *Marine Environmental Research* (2022): 105701.
6. Nadporozhskaya, Marina, Ninel Kovsh, Roberto Paolesse, and Larisa Lvova. "Recent advances in chemical sensors for soil analysis: a review." *Chemosensors* 10, no. 1 (2022): 35.
7. Nyika, Joan, and Megersa Dinka. "A scientometric study on quantitative microbial risk assessment in water quality analysis across 6 years (2016–2021)." *Journal of Water and Health* 20, no. 2 (2022): 329-343.
8. Pasarakonda, Satya Lakshmi, Srikanth Ponnada, Demudu Babu Gorle, Rapaka S. Chandra Bose, Anjali Palariya, Maryam Sadat Kiai, Hima Bindu Gandham, Murugavel Kathiresan, Rakesh K. Sharma, and Annapurna Nowduri. "On the role of graphene oxide in bifunctional Ni/MOF/rGO composites in electrochemical nitrate detection and oxygen evolution reaction." *New Journal of Chemistry* 47, no. 2 (2023): 725-736.
9. Uprety, Yadav, Hugo Asselin, Yves Bergeron, Frédérik Doyon, and Jean-François Boucher. "Contribution of traditional knowledge to ecological restoration: practices and applications." *Ecoscience* 19, no. 3 (2012): 225-237.
10. World Health Organization. *Guidelines for drinking-water quality: incorporating the first and second addenda*. World Health Organization, 2022.