Journal of Science Research International (JSRI)
ISSN: 2456-6365 (Online)

REVIEW PAPER

WATER QUALITY MONITORING USING BIOSENSORS

Suparna Deepak*, K Aditi Raju, Sneha Mohan and Akshay Devkar

Department of Biotechnology,

Pillai College of Arts, Commerce and Science (Autonomous), New Panvel, Maharashtra

**Correspondence author E-mail: suparnadeepak@mes.ac.in*

Received: 02 November 2025	Revised: 02 January 2026	Accepted: 14 January 2026	Published: 30 January 2026

***DOI:* https://doi.org/10.5281/zenodo.18479345**

Abstract:

Water contamination is of great concern in today's world, which has led us to take steps for management of the water quality. For improving management practices, it is important to understand the contaminants present in the water, we use biosensors to identify the type of contaminant present in the water sample. In this paper we have discussed various biosensors and how they are used in water quality monitoring.

Keywords: *Biosensors, Water contaminants, Electrochemical biosensors, Transducers, Microfluidic Sensors.*

Introduction

Water is very important to human life and to many industries for production of purpose. The most of water on Earth is present in the saltwater of the oceans, freshwater is required for lots of day-to-day human activities. However, maximum freshwater is locked up in glaciers and polar ice caps. Water resources are drawn mainly from rivers, lakes, and groundwater. The water cycle renews water resources through shifting water from the oceans, as freshwater, to land (1).

Demand of freshwater

India uses more water than our neighbourhood country. Indians are the most freshwater consumers in the world. Around 65% of India's whole water demand is dependent on groundwater, which performs a very important function in shaping the nation's financial and social development. The agriculture, home and industrial use, respectively, contains India's most use of water. Therefore, with developing demand for water and depletion of the present water on earth, the problem of freshwater availability is mainly increasing with developing countries (2).

Freshwater demand in India is very quickly overtaking the availability of water. In some areas of the country, it has already happened. The fast increase in population, urbanization and industrialization has led to a tremendous increase in water requirement. In the subsequent decade the demand in water is predicted to increase by 20 percent, fuelled specifically by industrial requirement which is projected to double from 23.2 trillion liters at existing to 47 trillion liters. Domestic demand is predicted to increase by 40% from 41 to 55 trillion liters and irrigation will require only 14% more in ten years. By data of the Ministry of Water Resources, per capita water availability in 2025 and 2050 is estimated to come down by nearly 36% and 60% respectively of the 2011 report. This demand is predicted to expand dramatically in future (2).

Problems

By shortage of freshwater many problems are created.

1. **Lack of Drinking Water:** Water is important for good health in humans. When there is a water shortage, human beings and animals lack sufficient water to drink, thus affecting their lives and health and wildlife is majorly affected.
2. **Shortage of water for agriculture:** Water is very important for agriculture and plants. Due to this, crops are not grown properly and cause shortage of food in the world. Thus, a drought-like situation occurs on earth so oxygen concentration on earth is also decreasing.
3. **Spreading of bacteria and parasites:** Water is used for bathing. During water shortages, people remain long before taking a shower. Dirty bodies and poor hygiene make them prone to infections and parasite attacks. Because of this, humans are infected by many dangerous diseases and many people die from diseases.
4. **Sanitation problems:** Lack of water makes cleansing dishes, houses, clothes, and different household items very challenging. In addition, unhygienic conditions are no longer suitable for an individual's health. The unhygienic conditions cause many diseases and bad smells coming from houses.
5. **Lack of education:** In arid areas, kids abandon school and help their parents in searching for water. During drought, some kids become weak and can't attend school (3).

Different methods available for quality monitoring: The perfect assessment and estimate of water quality ranges have become essential as river and lake water quality is crucial to human and economic growth. The cornerstone of environmental protection work is water quality evaluation, which is a crucial issue of water environmental monitoring and management.

1. The physical parameters such as checking water pH, turbidity and metal impurities are determined by methods such as digital turbidimeter, amperometry, and ion selective field effect transistor (ISFET).
2. Chemical materials such as fluoride, iron and Mn are usually found in groundwater whereas nitrogen (N) and pesticides are found in water as the result of human activities. These chemical materials can be determined by atomic absorption spectrometer and chromatography.
3. Microbial contamination can be determined by methods such as most probable number (MPN) and membrane filtration.
4. Microwave methods: The most important task for water quality testing is detecting the water contaminants at low concentration continuously. The contaminants present in the water will change the dielectric permittivity and conductivity of contaminants in water. Hence, microwave methods can determine the contaminants based totally on the contrast of dielectric constant between contaminated and clean water. The modern microwave method offers an approximate estimation of the water

compositions. These methods include spectroscopy techniques, water quality sensors, and microfluidic sensors (4).

Biosensors: Biosensors work on the principle of signal transduction and biorecognition of elements. All biological materials including enzymes, antibodies, nucleic acids, hormones, organelles, and whole cells can be used as sensor or detector in a device.

The father of biosensors, Leland C. Clark, invented the Clark oxygen electrode, a pivotal device that allows real-time monitoring of a patient's blood oxygen levels.

Biosensor components are analyte, bioreceptor, transducers, and measurable signal detector.

Types of biosensors: On the basis of the transduction mechanism used, biosensors can be classified as electrochemical and electrical, optical, piezoelectric, gravimetric, and pyroelectric.

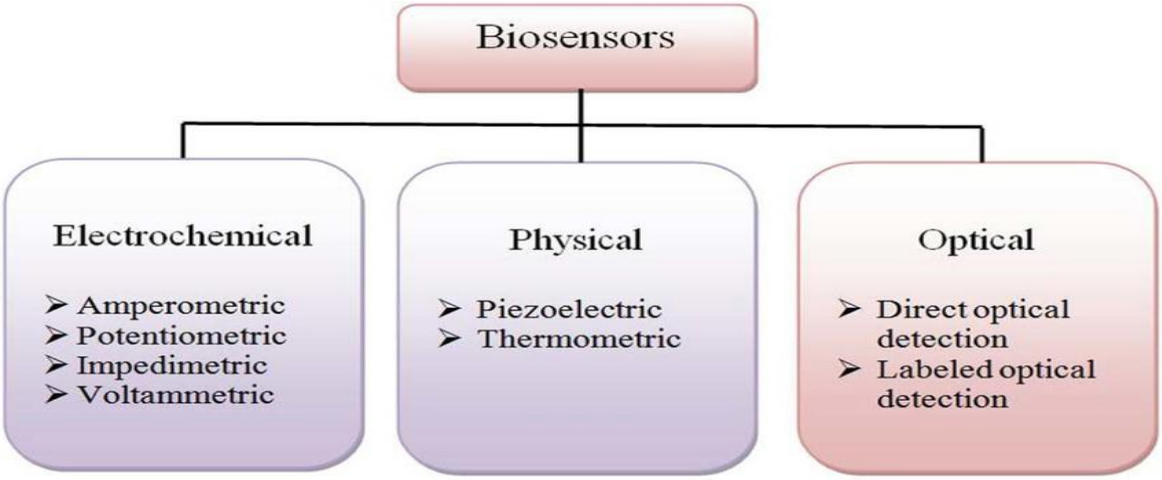

Figure 1: Types of Biosensors based on their transducer operation (5)

Transducers: The important function of Transducer in a biosensor is to transfer the signal of the desired analyte and bioreceptor's interaction into an electric signal. Transducers are specially in near touch with the bioreceptors and may detect small changes in light, heat pH, mass, and electricity. By changing it into a signal, the transducer ultimately helps researchers.

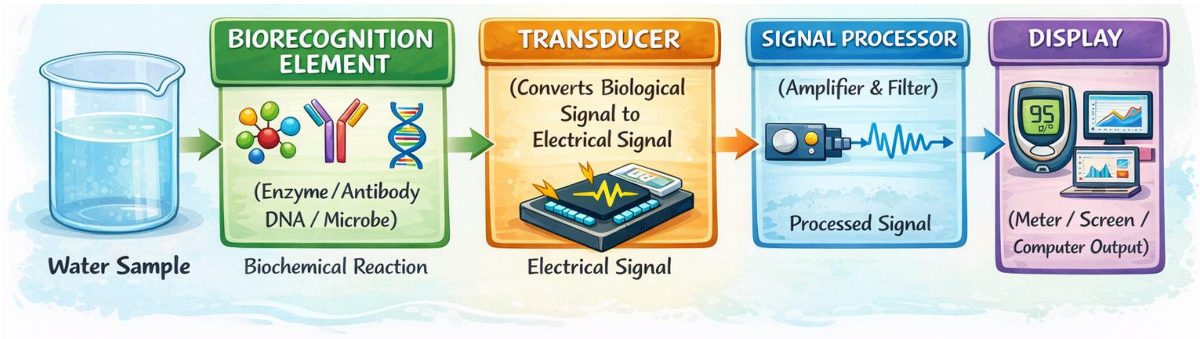

Fig 2: Important parts of biosensor

Types of transducers

1. Electrochemical**:** It's a reaction at electrode-electrolyte that takes place in interfaces and provides a switch for electricity to flow between 2 phases of different conductivity, i.e., the electrode and solid or liquid

electrolyte. They are made up from biological materials like a cell or tissue, enzyme electrodes. Ex. Redox electrodes, clark oxygen electrodes, field effect transistors.

2. Optical: Optical biosensors depend on the optical transduction of the signal and plug in ultraviolet, visible and infrared spectrophotometry in transmission and reflectance modes. Optical methods have been mainly used for monitor analyte concentrations. They are made up from enzyme immunological analytes. Ex. Photodiode, integrate optical sensors.
3. Piezoelectric: Piezoelectric biosensors are most commonly used in sound vibrations.

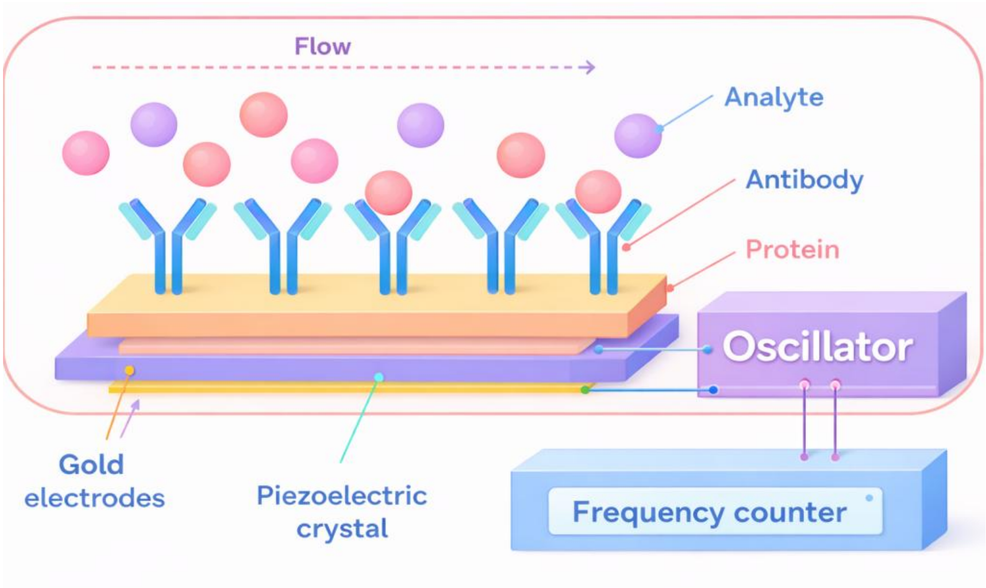

Figure 3: Piezoelectric biosensor

Features of biosensors

Biosensors have a two different kind of Components:

1. Biological: It interacts with it in such a manner which produces some physical change detectable by the transducer. Ex. Enzymes, antibodies.
2. Physical: They are outside the cell. Ex. Transducer, Amplifier.

Applications: Biosensors have come to be very famous in Coming years. They are extensively used in various fields. Biosensors are small in size and it can be easy to handle. They are specific and sensitive, and work in a reasonably priced manner.

Offline water sensing technology

Biosensors have a great potential towards monitoring the quality of water in their simplest, compact designing and due to cheapness. As an online and offline monitoring method can be considered for an *i- situ* system.

CNT sensor

It is an inexpensive sensor which can be incorporated into the real time monitoring data acquisition systems to make an alternative for the expensive setups. These carbon nanotubes are described as the roll of graphene, or a single sheet of carbons arranged into the hexagon cell shape. They are rolled up sheets of graphene with axial symmetry. These graphene layers depend on single walled CNTs (SWCNTs), double walled CNTs (DWCNTs), and the multi walled CNTs (MWCNTs). The diameters of SWCNTs are 0.4–200 nm and length of 100 nm–10 μm, MWCNTs are 1–300 nm in diameter and 1–150 μm in length. CNTs purity and their density or wrapping to an armchair, chiral or zigzag way, the diameter of the nanotube, its interspacing will reflect on their optical, thermal and electrical properties.

There are three major techniques which are employed in the production of CNTs:-

i. ***Carbon arc-discharge technique:*** It is two carbon electrodes which are kept in a vacuum chamber and connected to a DC power source. When the electrodes are kept closer, it guides the system an electric arc occurs. Graphite anodes which are made from the mixture of Co, Ni, S and Fe are also used. It is the cheapest method.
ii. ***Laser-ablation technique:*** It is made of a chamber containing vacuum inside and around 500 torr is maintained by filling helium gas or argon into it. The plasma plume is formed when extreme hot clouds of evaporated particles are formed and when further heated by the laser beam. Then the plasma plume is expanded and cooled. When the plasma cools during the expansion along with the steep temperature gradients, atoms, and small carbon molecules together with the metal catalyst.
iii. ***Catalytic chemical vapor deposition (CVD):*** It is a technique which involves chemical decomposition of gaseous or volatile carbon compounds into metallic nanoparticles that results as a catalytic as well as nucleation sites for initial growth of CNTs. Most popular chemical vapour deposition is thermal CVD, microwave CVD, oxygen-assisted CVD, radiofrequency CVD, hot-filament CVD, etc. (5)

2. Paper based sensor

On-site the quantification of colorimetric monitoring of water quality can be conducted by using the paper based sensors. The system contains a paper based analytical device (μPAD) which will produce the colorimetric signals that depends on the concentration of the specific target, and a cell phone equipped with the camera for capturing the image of two μPAD among one which will be tested with the water sample and the other will be tested with clean water sample used as control (6).

Cell phones can be used for data collection and to push data to a website where data is displayed on a map. Areas of contamination become easy to spot and can trigger additional monitoring to take place (6).

3. Amperometric biosensor

3.1 Horseradish peroxidase (HRP): It is a heme-containing glycoprotein which is used for the determination of hydrogen peroxidase. It is used more because of its high purity and low cost, and it is a privileged enzyme for sensing purposes. Substrate and H_2O_2 react to form the product with H_2O. It is modified with the absorbed ferrocene-modified HRP (7).

4. ALGADEC

It is a semi-automated portable device which contains a reservoir for antibody, substrate and washing buffer along with the flow cell unit for hybridization. The flow cell unit with the additional inlet is required for applying the heat and cooled on the sample as per the requirement of the analysis procedure. A peristaltic pump transfers the reagents into the flow cell and finally into the waste reservoir (8).

5. Fluorimetric sensor

5.1 PTB7:PC70BM OP with all-polymer interlayers: It is a detector which is constructed on a glass substrate with pre-patterned indium tin oxide (ITO) and anode of 100 nm thickness. The glass chip is cleaned with the deionized water (DI) or acetone and isopropanol in sequential steps under the sonication and pre-treated with oxygen plasma for 6 min in 50 W. The deposition of the photoactive layer of PTB7:PC70BM which is approx. 100 nm thick is followed by spin coating with solvent mixture. The fabricated device is packed using epoxy under the UV light. The organic photodetector was characterized under the irradiation from a xenon lamp paired with the standard AM 1.5 global filter for the current density characterization. A monochromatic light is equipped for external quantum efficiency (EQE) determination (9).

5.2 Microfluidic chip: It is a transparent microfluidic chip which is made up of polymethylmethacrylate (PMMA). The chip has a main port of 3 mm in diameter and 1 mm in depth, eight tiny ports of 1 mm in diameter, eight microchannels of 4.5 mm in length and 0.2 mm in depth along with eight reaction chambers of approximately 3.6 mm in diameter. The channels and the chambers of this chip are pre-treated with oxygen plasma and interacted with silane-poly (ethylene glycol). In a stock solution with silane-poly (ethylene glycol), the chip is coated with it and incubated at room temperature for 30 min. The treatment has been enhanced to make the surface hydrophobicity for the channels and chambers more efficient (9).

5.3 Fluorimetric detection apparatus: NO_2^- has been detected in the reaction chamber of the PMMA chip. The fluorometric assay contains diaminofluorescein-2 (DAF-2) probe which obtains the high fluorescent product at 450 nm in the presence of nitrite. The fluorescent light passes through the pinhole of the black-transparent sheet which reaches the OPDs, while the sheet also prevents the inference of the stray light. The data is recorded from the source measure unit to a computer by using a USB/GPIB interface adapter (9).

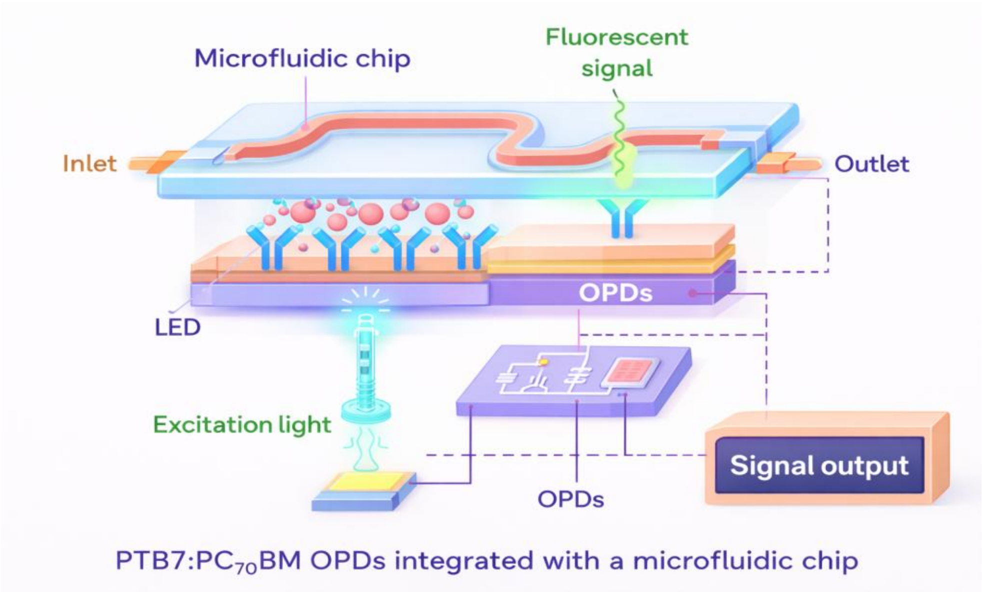

Figure 4: Fluorimetric biosensor with OPDs and microfluidic chip

Online water quality monitoring technology

Online technologies for water quality monitoring are more preferable than offline detecting technologies, online systems provide real-time data. Development and verification of predictive models are essential for understanding and managing water quality in real-time.

1. Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen consumed by aerobic microorganisms to digest the organic material present in the given water sample, at a given temperature, mostly 20°C, over a specific time period. An Important part of standard water quality analysis is to identify the BOD of the sample. The standard method for BOD determination- it is required to incubate an oxygen-saturated sample, after activated sludge, that is mixture of various microorganisms, is introduced, for 5, 7, 10 or 20 days (BOD5, BOD7, BOD10 or BOD20, respectively) at 20°C and other chemical analysis BOD test also need good laboratories, trained technician to obtain reproducible results, that makes the monitoring process difficult. Thus, the method is not suitable for process control in wastewater treatment (because it takes 5 days to complete) and the real-time monitoring of water environments, such as rivers, streams, ponds, and groundwater.

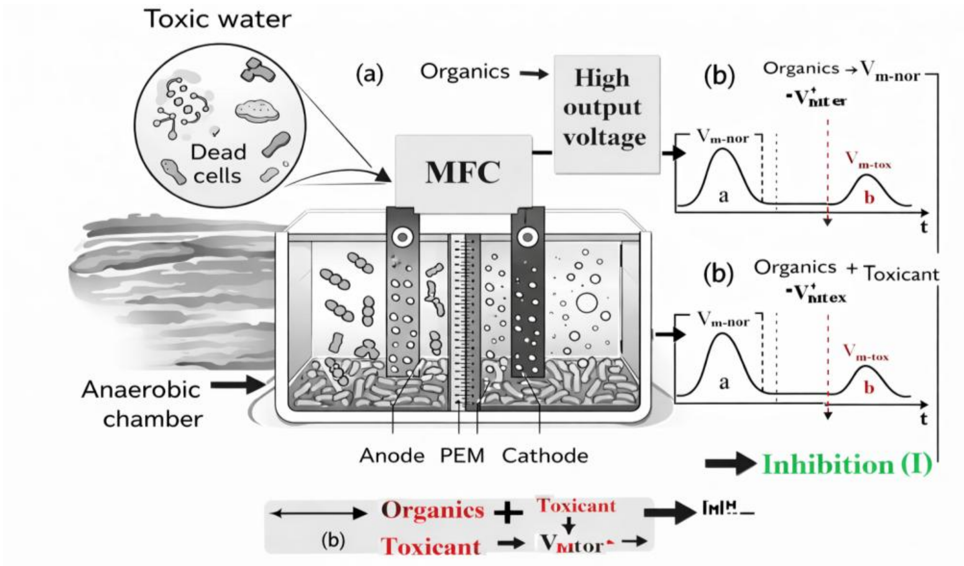

Figure 5: Schematic illustration of toxicity detection in water based on self-powered MFC

As shown in figure, the signal produced by the bacteria can be used to measure water quality because a change in water quality will result in a change in the electrical current or potential by passing a sample through the anodic region of the cell, any toxins present in the sample will affect the bacteria. This technique is being developed into a continuous, on-line, on-site system for monitoring water quality. A microbial fuel cell (MFC) uses bacteria to produce electrical energy. The Bacteria gain energy from the release of electrons to the anode. When the anode potential in the MFC-based biosensor changes, the bacteria that grow on the anode experience a change and enter a new energy level. Most of the MFC-based biosensors, which are used to detect either BOD or toxicity, use an external resistor in the external electrical circuit.

The bacteria oxidize a carbon source and donate their electrons to the first electrode, the anode. This causes a current to pass through an external circuit, thereby causing a reduction reaction at the second electrode, the cathode. A chemical signal—the oxidation of a chemical substrate—is thus translated directly into an electrical signal by billions of bacteria. The electrical signal produced depends on several environmental factors including pH, substrate availability, and the concentration of toxins (10). Pasternak *et al.* have developed a self-powered, autonomous BOD biosensor for online water quality monitoring based on signal frequency (11). Using this sensor, the level of urine contamination in water can be studied. As electroactive microorganisms are used to produce this biosensor, it is self-powered and can operate autonomously for five months.

Takahiro Yamashita *et al.* published a novel open-type biosensor for the in-situ monitoring of biochemical oxygen demand in an aerobic environment (12). In the study, a bioelectrochemical open-type biosensor was designed for the in-situ monitoring of BOD during intermittent aeration. The open-type anode, without any protection against exposure to oxygen, was inserted directly into an intermittently aerated tank filled with livestock wastewater. Anodic potential was controlled using a potentiostat. This study suggested that, due to the formation of a thick biofilm on the anode, the application scope of BES-based biodevices is extended from anaerobic to aerobic environments.

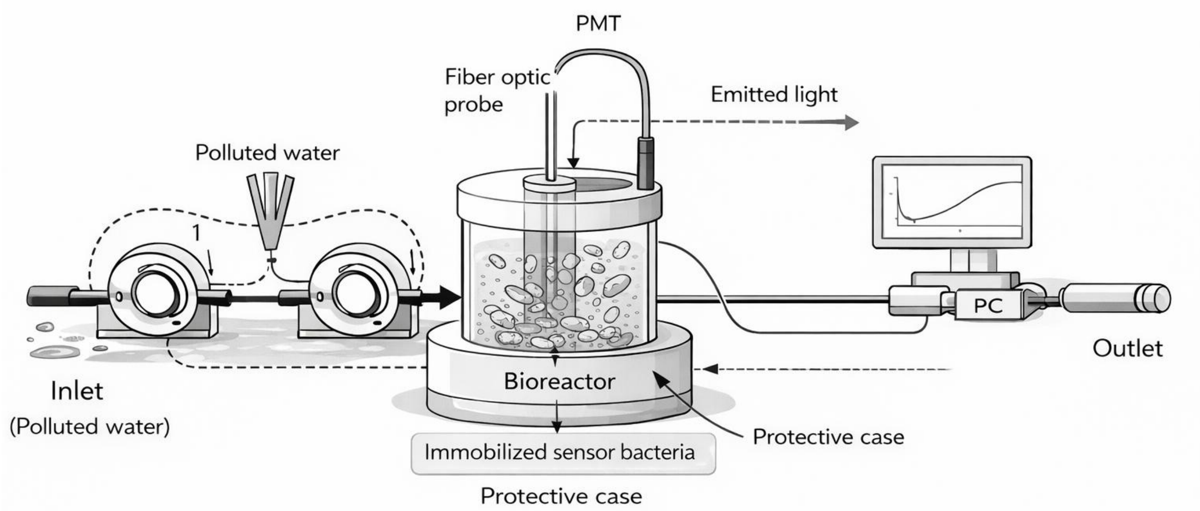

Figure 6: A schematic representation of the perspex flow unit of the on-line fibre-optic biosensing system based on immobilized bioreporter bacteria for monitoring water pollutants consisting of a fiber optic probe and peristaltic pumps; B. Photograph of perspex flow unit; and C. Calcium-polymerized alginate with six adlayers (adapted from Eltzov *et al.* (13)).

Researchers have also developed a prototype on-line fibre-optic marine MFC-biosensor with an integrated electrochemical cell, which can be used to determine assimilable organic carbon (AOC) in seawater in real time (14).

2. Heavy metals and disinfectants

Relatively, the half-life time of heavy metals is long, ranging from tens to hundreds of years, meaning it is barely reduced by microorganisms. Despite this, some of the metals are essential for human health. Heavy metals are known to inhibit the activity of enzymes, and application of this for the determination of these hazardous toxic elements offers several advantages, such as simplicity and sensitivity. Another advantage of whole-cell sensors is their ability to react only with the available fraction of metal ions, which is not possible with analytical methods.

Hassan *et al.* have published the on-line detection of heavy metals and other toxic chemicals in water using a sulfur-oxidizing bacteria (SOB)-based biosensor (15). Generally, in non-toxic water, SOB oxidizes elemental sulfur (S) to sulfuric acid (H_2SO_4), resulting in a decrease in pH, while sulfate increases the electrical conductivity (EC) of water. However, in the presence of contaminants, the activity of SOB is inhibited, resulting in an increase in pH and a decrease in EC. Therefore, changes in EC can be used as an indication of toxicity.

MFC-based biosensors are among the recently developed sensors that can be used for the detection of toxic components in water. It is a microbial fuel cell for onsite monitoring of toxicants present in water (16). MFCs are simple to operate and utilize microalgae for their working. They are sensitive, portable, and cost-effective bioelectrochemical sensors. This photo-MFC has been observed to be more efficient than other MFCs for onsite detection of formaldehyde and other contaminants, such as herbicides and pharmaceuticals, which pose a global environmental threat and concern.

Meghwani has developed an online biosensor for water quality monitoring and control in a swimming pool (17). The measurement and control system are based on National Instruments hardware and its software package LabVIEW, as shown in Figure 14. The device controls the disinfectant (calcium hypochlorite) dosage, water temperature, pH, and turbidity in order to continually maintain pool water disinfection.

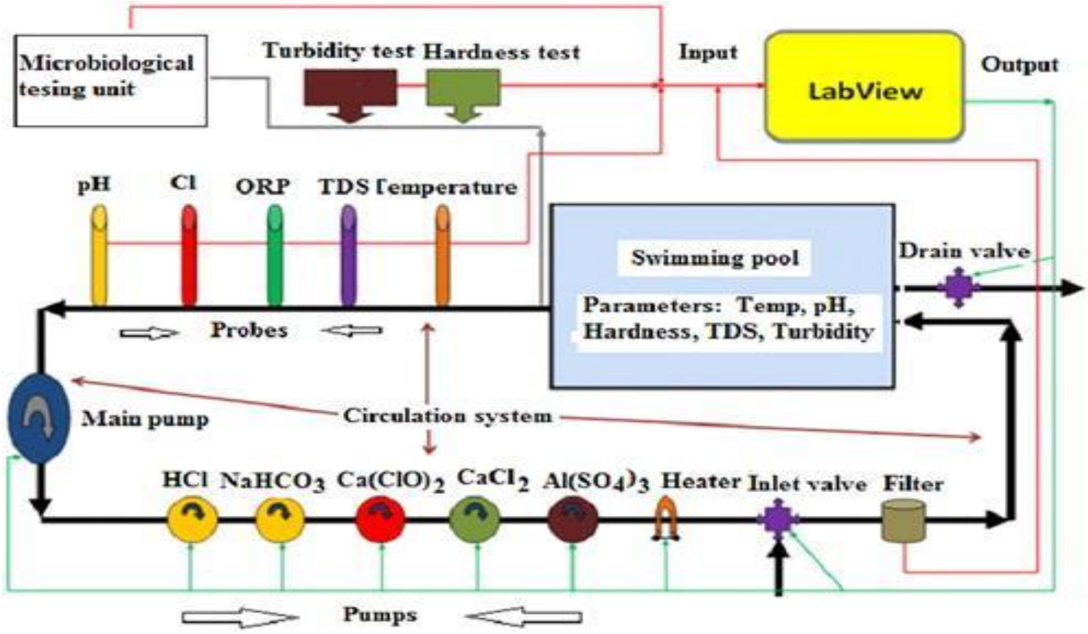

Figure 7: Schematic diagram of the swimming pool water quality monitoring and control system (adapted from Meghwani, 2017)

3. Pesticides and toxic substances

A microbial fuel cell was constructed from the biofilms of *Enterobacter cloacae* grown on the anode. Bioelectrocatalysis was observed when the biofilm was grown in media which had sucrose as its carbon source and methylene blue as the mediator. In the presence of arsenic, a decrease in bioelectrocatalytic current was observed. Biofilm growth in the presence of arsenic resulted in lower power outputs; however, an addition of arsenic showed no immediate result in the power output due to the short-term arsenic resistance of the bacterial culture and also due to the slow transport of arsenic across cellular membranes to metabolic enzymes (19).

Antibiotics are another group of pollutants of great concern due to the global threat of antimicrobial resistance and the excessive, and sometimes abusive, use of these compounds. A colorimetric biosensor for screening of several antibiotics (paromomycin, tetracycline, chloramphenicol, and erythromycin) inhibiting bacterial protein synthesis was applied for the detection of antibiotics in surface water. The method was based on the ability of these antimicrobials to inhibit β-galactosidase synthesis (20).

Derivatives of cellulose, like nitrocellulose membranes, have been applied as substrates in paper-based devices. These membranes are naturally hydrophobic and demonstrate adequacy for the immobilization of enzymes and proteins by electrostatic interactions. The sensors were fabricated using Grade 1 Whatman filter paper. The paper was inkjet printed with a substrate zone and a sensing (biomaterial) zone. The substrate and biomaterial (enzyme) were entrapped within a silica matrix in a sandwich configuration. The colorimetric signal intensity of the sensing zone was either evaluated using the naked eye or quantified using an office scanner/cell phone with ImageJ software. This sensor can detect pesticides rapidly and with high sensitivity without the use of instruments or reagents. The paper sensor can also detect heavy metals (Hg(II), Cu(II), Ag(I), Cd(II), etc.) approximately within 10 min, with low detection limits. Paper-based sensors have also been developed for the simultaneous detection of pathogens (e.g., *E. coli* O157) and total coliform bacteria in water, food, and beverage samples. The colorimetric detection enables the use of paper sensors in remote areas for rapid detection (21).

4. E. coli

In recent years, Peixoto, Machado *et al.* worked on bioactive paper sensors for online monitoring of water quality. In this work, a method for selective and ultra-sensitive multiplexed detection of *Escherichia coli* (non-pathogenic or pathogenic) using a lab-on-paper test strip based on intracellular enzyme (β-galactosidase or β-glucuronidase) activity was reported. The sensor is recognized for its rapid, sensitive, online monitoring of toxins, heavy metals, and bacteria, without the need for advanced instrumentation or trained personnel (22). This biosensor is an equipment with online data transfer provision for detecting and controlling water quality and enhancing water treatment procedures. The instrument is capable of detecting at least two colony-forming units of *E. coli* in approximately 8 hours.

Jung and Lee developed an optical biosensor for automated, real-time monitoring of microbial colony formation and growth in water. The system dynamically detects individual micro-colonies using sub-pixel sweeping microscopy with high resolution. The real-time bacterial micro-colony-counting system, implemented on a wide field-of-view on-chip microscopy platform (ePetri), exhibited the capability to dynamically track individual bacterial micro-colonies over a wide field-of-view without requiring a moving stage (23).

5. Endocrine Disrupting Compounds (EDCs)

Increasing attention has been observed toward endocrine disrupting compounds as pollutants in municipal wastewater. Recent studies have proven that these compounds can have adverse impacts on the environment and are often not efficiently removed in wastewater treatment plants (24). Biosensors have been developed to determine EDCs by measuring the presence of estrogen receptors. The binding capability of chemicals toward estrogen receptors can be determined using biosensors such as surface plasmon resonance biosensors for the measurement of estrogens and xenoestrogens. Estrogenic activity in water can also be determined using optical biosensors produced by recombinant cells co-expressing human estrogen receptors. A multi-channel, two-stage mini-bioreactor based on genetically modified bioluminescent bacteria is used for the detection of toxicity of certain EDCs. Other biosensing mechanisms include cell proliferation, luciferase induction, ligand binding, antigen–antibody interactions, and vitellogenin induction (25).

Conclusion

Depending on the types of biological elements and transducers employed a wide variety of biosensors are available. Biosensors can be used for the rapid monitoring of water quality with a high specificity to a wide range of analytes, both in online and offline systems. Offline systems are preferred to perform various hybrid techniques. This allows the monitoring of water pollution and its quality also holds a wide range of potential for analyzing the drinking water or even the biological samples. These techniques can also help in reducing the risk of aquaculture and tourists sectors who are most affected by the toxic algal blooms. Online systems are preferable as they help in obtaining continuous real-time data. They also provide early warnings of the spread of diseases by monitoring toxins or bacteria in the samples. Commercial-scale application of biosensors is, however, still limited. Advances in nanotechnology, biotechnology, microelectronics, and other fields can be used to improve biosensor technologies.

References

1. Water supply and demand. (2022). *Encyclopedia Britannica*.
2. Ahmad, T., *et al.* (2019). Groundwater depletion and freshwater demand in India. *Journal of Water Resource Studies*.
3. Olivia, L., *et al.* (2022). Impacts of water scarcity on health, sanitation, and education. *Environmental Research and Public Health*.
4. Josephine Ong Ning Ting, *et al.* (2020). Microwave-based sensing techniques for water quality monitoring. *Sensors and Actuators A: Physical*.
5. Nasture, A. M., Stamatin, I., & Moldovan, A. (2022). Carbon nanotubes: Synthesis methods, properties, and applications. *Materials Today: Proceedings, 62*, 742–749.
6. Sicard, C., Glen, C., Aubie, B., Wallace, D., Jahanshahi-Anbuhi, S., Pennings, K., … Filipe, C. D. M. (2015). Tools for water quality monitoring and mapping using paper-based sensors and cell phones. *Water Research, 70*, 360–369.
7. Marzo, A. M., Mayorga-Martinez, C. C., & Merkoci, A. (2020). Electrochemical biosensors based on horseradish peroxidase: Principles and applications. *Biosensors and Bioelectronics, 161*, 112–128.
8. Diercks-Horn, S., Taudte, R. V., Behrmann, O., & Knecht, E. (2018). ALGADEC: A portable biosensor system for on-site detection of algal toxins. *Biosensors, 8*(4), 112.
9. Pires, N., Dong, T., Yang, Z., & Hoivik, N. (2018). Integrated fluorimetric biosensing platforms using organic photodetectors and microfluidic chips. *Sensors and Actuators B: Chemical, 255*, 173–181.
10. Yang, C., Zhang, W., Liu, S., & Zhang, Y. (2019). Microbial fuel cell–based biosensors for water quality monitoring: Fundamentals and applications. *Biosensors and Bioelectronics, 141*, 111–120.
11. Pasternak, G., Greenman, J., & Ieropoulos, I. (2017). Self-powered, autonomous biological oxygen demand biosensor based on microbial fuel cell technology. *Sensors and Actuators B: Chemical, 244*, 815–822.
12. Yamashita, T., Kimura, Z., Kanno, M., & Watanabe, K. (2016). An open-type bioelectrochemical biosensor for in situ monitoring of biochemical oxygen demand under aerobic conditions. *Biosensors and Bioelectronics, 77*, 102–108.
13. Eltzov, E., Marks, R. S., & Voost, S. (2015). Fiber-optic biosensing systems based on immobilized bioreporter bacteria for the monitoring of water pollutants. *Biosensors and Bioelectronics, 70*, 237–243.
14. Hassan, S. H. A., Kim, Y. S., & Oh, S. E. (2019). On-line detection of toxic compounds in water using sulfur-oxidizing bacteria-based biosensor. *Sensors and Actuators B: Chemical, 297*, 126737.
15. Chouler, J., Padgett, G. A., Cameron, P. J., & Di Lorenzo, M. (2019). A photosynthetic microbial fuel cell for on-site sensing of water toxicity. *Biosensors and Bioelectronics, 128*, 147–153.
16. Meghwani, D. (2017). Development of an online biosensor system for swimming pool water quality monitoring and control. *International Journal of Instrumentation and Control Systems, 7*(2), 1–10.
17. Pasternak, G., Greenman, J., & Ieropoulos, I. (2017). Self-powered, autonomous biological oxygen demand biosensor for online water quality monitoring. *Sensors and Actuators B: Chemical, 238*, 1231–1239.

18. Meghwani, S. (2017). *Online biosensor for swimming pool water quality monitoring and control* (M.Tech thesis). National Institute of Technology, India.
19. Yang, C., Wang, Y., Zhang, G., & Logan, B. E. (2019). Electrochemical biosensors based on microbial fuel cells for water quality monitoring. *Biosensors and Bioelectronics, 132*, 274–284. https://doi.org/10.1016/j.bios.2019.02.012
20. Pasternak, G., Greenman, J., Ieropoulos, I., & You, J. (2017). Self-powered, autonomous biological oxygen demand biosensor based on a microbial fuel cell. *Sensors and Actuators B: Chemical, 244*, 815–822. https://doi.org/10.1016/j.snb.2017.01.060
21. Sicard, C., Glen, C., Aubie, B., Wallace, D., Jahanshahi-Anbuhi, S., Pennings, K., Daigger, G. T., Pelton, R., Brennan, J. D., & Filipe, C. D. M. (2015). Tools for water quality monitoring and mapping using paper-based sensors and cell phones. *Water Research, 70*, 360–369. https://doi.org/10.1016/j.watres.2014.12.005
22. Peixoto, P. S., Machado, A., Costa, R., Faria, M. A., & Pereira, C. M. (2019). Bioactive paper-based sensors for multiplexed and ultra-sensitive detection of *Escherichia coli* in water. *Biosensors and Bioelectronics, 130*, 156–163. https://doi.org/10.1016/j.bios.2019.01.036
23. Jung, J. H., & Lee, S. J. (2016). Optical biosensor for real-time monitoring of bacterial micro-colony growth using sub-pixel sweeping microscopy. *Biosensors and Bioelectronics, 75*, 27–34. https://doi.org/10.1016/j.bios.2015.08.020
24. Woldu, A. (2022). Occurrence, impacts, and removal challenges of endocrine disrupting compounds in wastewater treatment plants. *Environmental Science and Pollution Research, 29*, 12345–12358. https://doi.org/10.1007/s11356-022-xxxx-x
25. Sanseverino, I., Eldridge, M. L., Layton, A. C., Easter, J. P., Yarbrough, J., Schultz, T. W., & Sayler, G. S. (2009). Estrogenic activity monitoring in water using biosensors based on recombinant bioluminescent bacteria. *Environmental Science & Technology, 43*(18), 7131–7136. https://doi.org/10.1021/es901181b