A comprehensive review on microbial biosensors

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ABSTRACT

Biosensors are one of the most important and valuable inventions of the past few decades. These have helped in overcoming the shortcomings of the conventional methods of analyzing which are very time-consuming and also costly. The bioreceptor and the transducer together form the biosensor. The bioreceptor is the biological sensing component that detects the analyte and then the transducer is the physicochemical detector that produces signals by detecting any activity in the bioreceptor. There are different types of biosensors depending on the types of bio receptors used like enzyme biosensors, microbial biosensors, and affinity biosensors. Based on the kind of transducer used, there are electrochemical, physical, and optical biosensors. In microbial biosensors, micro-organisms are integrated with different types of transducers. These are cost-effective, sensitive, and reliable as compared to other types. Microbial biosensors are successfully used as a screening aid in environmental monitoring, clinical and research sectors, food, and agriculture industries. In recent years due to the concern for the environment and also to decrease the labor intensity, there is a growing application of microbial biosensors in every possible way. This paper reviews the design, applications in various industries, current advances, and the future perspective of microbial biosensors.

Keyword - *microbial biosensor, amperometric biosensor, conductometric biosensor, diagnostics microbial biosensor, microbial fuel cell*

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1. Introduction

The biosensor concept goes back to 1962 when Leland C Clark and his co-workers established the electrodes by using immobilized enzymes on the electrochemical detectors. They act as enzyme electrodes that help expand the range of the base sensor. The first microbial biosensor was created by Divines in1975. This biosensor had an oxygen electrode with the bacteria *Acetobacter xylinum*. They act as enzyme electrodes that help expand the range of the base sensor. A biosensor is a scientific device developed to do analytical procedures and consists of two parts: the transducer and the bioreceptor. In a biosensor, the bio element or the bioreceptor contains the enzyme in enzyme biosensors, microbes in microbial biosensors and also materials like tissues, antibodies, cell receptors, nucleic acids, cell organelles from different living organisms. The transducer which is the physicochemical detector component works in close contact with the bioreceptor and generates signals that indicate the quality and quantity of the specific substance. These signs could be the consequence of changes in fixation, protons, take-up or arrival of gases, light emanation, or ingestion caused because of the digestion of the analyte by the bioreceptor. The signals produced by the receptor are converted into responses that can be measured easily like current, potential or even absorption of light through optical and electrochemical means which can be amplified and even processed and studied.

A microbe or its enzymes and organelles are connected to electrodes and so to a transducer, that converts the biological reaction into electrical signals in microbial biological sensors. The various enzymes present within the microbial cell is the bio element. The enzymes within the cell trigger a really specific and selective reaction to the substance. enzyme biosensors are most generally used and additionally since pure enzymes are being employed the specificity and response are far better than the other biosensors however as multiple enzymes and cofactors are needed to be purified it is a very long process and also very expensive. Microbial sensors, on the other hand, are little or less time-consuming compared to others, with no need for purification, and additionally, a quick response is obtained. [1]The microorganisms have to be integrated into the transducer for the sensor to provide reliable results. The microbial cells are immobilized with the help of chemical and physical strategies like adsorption, encapsulation, covalent binding and crosslinking, and so forth. The immobilization between the microbe cells and also the transducer should be stable and intimate for the transfer of responses or specific signals from the bio element to the transducer. Chemical and physical procedures being used for immobilization have less stability and also several disadvantages, therefore recently nanomaterials are used like nanoparticles, fiber optics, and nanotubes that support the steadiness and additionally will increase the response of the biological element within the biological receptor. The transducer is a vital half and classified into optical biosensors, electrochemical biosensors, microbial fuel cells, etc. Thanks to its numerous benefits like stability, low cost, and quick response compared to other varieties it's employed in different fields akin to the food and fermentation business for detection of biomolecules like carbohydrates, environmental monitoring, and also clinical research and studies.[2]

2. MICROBIAL BIOSENSOR DESIGN

Living and nonliving cells can be used for microbial biosensors. Once the cell outer wall, the semipermeable membrane is removed, permeabilization is claimed to be done and therefore the periplasmic contents are exposed however in the case of the viable cells employed in the biosensors, they are dependent on the respiratory and metabolic functions of the cell, during this case, the analyte will be either the inhibitor or substrate of those functions like antibody-antigen. Bioreceptors used are membranes or gel strips of different biomaterials that contain immobilized microorganisms entrapped in the surface of the physiochemical element

2.1 Immobilization

Immobilization adds to the standard of the signal transmitted and will increase the reusability of the biosensor and additionally its shelf life. and the greatest advantage is that there will be low consumption of biological materials but high analysis after cell fixation. In the biosensor, cells could either be actively or then passively immobilized microorganisms has the aptitude to make adhesions on the stratum or alternative surfaces and this ability of microorganisms are used in the passive methodology and therefore the active method uses different chemical and physical strategies to fix the cell to the surface.

2.1.1 Chemical methods of immobilization

Valence bonding and cross-linking are the chemical fixation methodology. The development of bonds between the bio component, which is the microorganism cell membrane, and the transducer is necessary for covalent attachment. The nucleophilic functional agencies found in the amino alkanoic acid chains of indole, carboxylic, proteins, hydroxyl, thiol, threonine, and many other organic compounds are often used to form the bonds. The form of the transducer membrane remains constant and for effective incapacitation to occur, cells are exposed to brutal conditions that may result in harm to the semi-permeable membrane as well as a decrease in the chemical activity of the cell, causing it to lose survivability. A bridge is established between the functional groups in the cell's outer membrane that can eventually form a network.Crosslinking is most well-liked over valency binding because it is way quicker and additionally an easy methodology and since the bonds shaped are robust there are fewer probabilities of losing the catalytic activity and natural action and viability and stability. Crosslinking could happen in two ways in which are direct binding wherever microbe cells bind to the transducer or indirect binding where the cells bind to the support membrane then placed on the transducer. [3]

2.1.2 Physical methods of immobilization

Once viable cells are needed physical strategies of immobilization like entrapment and surface assimilation are preferred, adsorption is probably the foremost basic method, and it's obsessed with the physical connection with the carrier surface and that of the microorganism. Throughout this technique, the materials like immobilization matrices made up of glass beads and alumina, membranes, filter paper, and different carbon materials having high absorbance are used and so the microbe cells are kept undisturbed with them within the buffer solution. Generally, cells are directly absorbed onto the surface of the electrode. Adsorption being easy could also be a stable methodology but the immobilized cells won't retain the activity for terribly long.

In the method of entrapment, the microbe cells are entrapped within the layers of matrix or fibers and this procedure is irreversible. The matrices used for immobilization have such a property that it will alone retain the desired molecules and the rest can simply move ahead and then are discarded. Biomaterials used for the matrices entrapping the cells are agar, cellulose, epoxy, and photograph crosslinked resin, and different compounds like polystyrene, polyester, carrageenan, and polymer, etc. The performance of the biosensor is in most cases restricted by immobilization, hence as technology is advancing nanotechnology is successfully being utilized within the designing of a biosensor and also the nanostructures are employed for immobilization

2.1.3 Nanostructures

Nanoparticles, nanotubes, and fiber optics are currently widely being employed in microbial biosensors. Carbon nanotubes that are preferred for biosensors should have good electric properties, large surface area, chemical, and catalytic stability, and well as higher battery charging. Fiber is employed for the fast detection of substances. A microbial biosensor with flow-through fiber optics was made up for the detection of toxicity in water. Fiber optics-based sensors also are developed for air toxicity analysis.[4]

3. CLASSIFICATION OF MICROBIAL BIOSENSOR

Based on the principle of detection of the analyte electrochemical microbial biosensors are of the following types

3.1 Based on the electrochemical properties of the transducer

3.1.1 Amperometric microbial biosensor

This type of biosensor is the most widely used microbial biosensor. The biosensing elements are bacteria like *Pseudomonas putida, Bacillus subtilis* or the hay bacteria, *thermophilic bacteria* that can survive high temperatures, *Serratia marcescens*, and fungi *Trichosporon dermatospora*. The current produced by the ion exchange reactions that take place can be followed with the help of different species on the electrode's surface and then corresponds with the specific analytes. This type of biosensor is used for measuring the biological oxidation demand so that biodegradable toxic and harmful pollutants can be detected.

BOD5 is the name given to the process where the BOD of samples is measured within a span of 5 days using the traditional methods. This is a very time-consuming process hence is not useful for online analysis and is now being replaced by aminopteric microbial biosensors. Usually, a mixture of two or more microorganisms is used to broaden the spectrum of the substrate and analyte to increase efficiency and ensure stable performance. Flow analysis is adopted which lets the sensor carry out monitoring and online detection.

An amperometric microbial biosensor having O2 electrodes and with activated sludge was developed and applied to the monitoring of the life of an anaerobic reactor. Phenol and its substituted compounds are carcinogenic and extremely harmful to humans and any other organisms. A kind of aminopteric microbial biosensor was developed to detect these compounds with *p.putida* immobilized graphite-epoxy composite electrodes with carbon nanotubes. Another model genetically engineered *Escherichia coli* strain which is sensitive to chemicals to detect about 1.6 PPM phenol within 20 minutes. Based on cellular respiration to *pseudomonas SP* which was entrapped in a polycarbonate membrane modified oxygen electrode could detect p-nitrophenol. Organophosphates that are neurotoxic are used in pesticides and insecticides and also in chemical warfare. With the help of genetic engineering, *P. putida* with surface-expressed organophosphorus hydrolase are developed which are sensitive for the detection of organophosphate. There are biosensors that use *Saccharomyces cerevisiae* for cyanide monitoring and also this type of microbial biosensor can also be employed for the detection of hydrocarbons like ethanol and simple glucose during fermentation of alcoholic drinks and other food products. [5]

3.1.2 Potentiometric microbial biosensor

The electrodes in potentiometric microbial biosensors are conventionally ion-sensitive electrodes like ammonia, chloride, or gas-sensitive electrodes which are coated with a layer of immobilized microorganisms. When these microbes consume the analytes there is a generation of potential concerning the ion accumulation or depletion. The signal produced gives information about the quantity of the substance present for analysis as the transducer measures the different potentials between the working and the reference electrode in the device. To incorporate a wide range of detection very stable hence reliable and sensitive transducers are needed. A biosensor that works based on a pH electrode having *Flavobacterium sp* with organophosphates as a target was created having a detection limit between 0.025-0.4 mM. When recombinant *Escherichia coli* has been used the limit of detection increases to 2µ- 3µM. The process is dependent on the identification of the positive ions released by organophosphorus hydrolase catalyzed hydrolysis of organophosphate. For the detection or monitoring of the growth of penicillin potentiometric microbial biosensors with genetically modified *Escherichia coli* having plasmids that code for **β**-lactamase and penicillinase and immobilized using gluten and acetyl cellulose membrane entrapments a developed. There are pH electrodes like when ammonium ion-selective electrodes are used with *Bacillus sp* which have high yield and are used to identify Urea in milk. Oxygen electrodes are used for the detection of Ethanol with *S.ellipsoideus* and sucrose with *s. Cerevisiae.*

3.1.3 Conductometric microbial biosensor

Conductometric biosensors are fast and sensitive. When microbes catalyze a reaction there will always be a fluctuation in the quantity of the ionic species hence there will be a net difference in the conductivity of the reaction solution. Detection of conductance of the solution will be very not perfect but the conduct and Measurement are highly sensitive conductometric biosensors with c. vulgarus bio algae was developed to detect the pesticides used in agriculture and metal ions like cadmium and Zn2+. There are conductometric microbial biosensors with entrapped lyophilized *brevibacterium ammoniagenes* with pt twin wire electrodes. Sure the catabolic activity of the bacteria produces ammonia from urea, and hence the local pH increases. A change in pH value will cause a change in sensitivity, which is detected by the working electrode.

3.1.4 Voltammetric microbial biosensor

The voltammetric microbial biological sensor was developed to identify metal ions like Cu2+ by using *circinella sp.* Here the current is measured using the controlled variant of potential.

3.1.5 Impedimetric microbial biosensor

Impedimetric microbial biosensors are developed by immobilizing bio-element on the transducer. Signals are produced by monitoring and measuring the analyzed through the electrical impedance signal which is produced proportional to the analyte activity, that is the impedance will fluctuate depending on the analyst, as the analyst binding increases with higher analyte concentration then, the impedance across the electrode surface changes. There are various advantages like high-sensitivity, label-free, less costly, and not being affected by the presence of another analyst, ease of miniaturization, and integration with other technologies, but there are also disadvantages like non-specific binding variable reproducibility and limit of detection.

3.2 Based on the optical properties of the transducer

The optical biosensor is the maximum sensitivity and powerful method. In this method, each affinity and catalytic reaction may be measured. During the reaction, there's an extra charge in the optical properties such as fluorescence, absorption, luminescence, and refractive index, and optical fibers track those properties to detect the analyte. This kind of microbial biosensor has many benefits along with selectivity, flexibility, sensitivity, compactness, resistance to electric noises and it may be used with no disruption from the electric or magnetic field from the surroundings. Along with the benefits, there also are a few hazards like there are drawbacks with the long-time period stability of this kind of biosensor, and additionally it has a protracted reaction time

3.2.1 Bioluminescence microbial biosensor

The dissipation of light by living organisms is characterized as bioluminescence and this is a naturally occurring phenomenon and is widely used. This phenomenon is very helpful in real-time monitoring. The luminescence change is caused by the lux genes coding for luciferase that will reciprocate to the target analyte based on the dose. Lux gene can be expressed in two ways by the organism that is in the constitutive or inducible way.

Constitutively, the lux gene exists in the sensing microbe and the bioluminescence will fluctuate where it is introduced to certain chemicals. On the basis that the light intensity produced by the bacteria could be diminished in the presence of toxic compounds, a *Vibrio fischeri* based bioluminescent microbial biosensor is there to quickly detect the common and harmful pollutants that contaminate the environment, especially air. To test the toxicity, another bioluminescent microbial biosensor based on the luxCDABE-marked *Acinetobacter sp* bacteria is used to detect pollutants like heavy metals that are released from industries through the contaminated wastewater The reporter gene that is this lux gene is connected to a promoter gene which is managed by presence and measure of the objective analyte in the inducible strategy. The inducible approach of detection is more advanced than the other method as it allows a more complex and specific detection of analytes even in a mixture. The genetically modified recombinant *Escherichia coli* PGRFM that carries the luxCDABE reporter gene that will be coupled with pgi promoter, which could be induced on the basis of the dose by methyl viologen was used to develop a new and more useful kind of biosensor based on the whole cell that can respond to conditions like oxidative stress. [6]

3.2.2 Fluorescence microbial biosensor

These are commonly used in chemistry when fluorescent light is emitted equivalent to the concentration of the substance to be analyzed. Based on the method for the determination of analyte concentration there are two kinds of fluorescent microbial biosensors: in vivo approach and in vitro approach. In the invivo type, a genetically engineered microorganism with a transcriptional fusion between an inducible promoter and a reporter gene encoding a fluorescent protein is used. [7]

The GFP pattern, which codes for the green-fluorescent proteins, is occasionally used as a reporter and thus consolidated to the host gene, allowing the reporter behavior to be evaluated in each and every cell. This category of microbial biosensor is used to evaluate the heterogeneity of iron bioavailability in plants. *Sinorhizobium meliloti* has the GFP efficiency combined with the melA promoter, and the inclusion of these characteristics allows them to identify galactosides.O2 sensing fluorescent material-based biosensors are frequently used to evaluate biological oxygen demand.

3.2.3 Calorimetric microbial biosensor

In this type of microbial biosensors, the quantity of the materials to be examined can be easily detected by the difference in the color of the compound. Here the method is sensitive. The detection is very easy as the color change can be observed with the naked eye. A biosensor was developed to identify organophosphates based on the PNP formed because of the hydrolysis of organophosphates by genetically modified *Escherichia coli*, which expresses organophosphate hydrolase on the cell surface and then leading to the production of toxins, causing visible discoloration of the cells. [8]

3.2.4 Microbial Fuel cell

A microbial fuel cell is an oxidizing device for inorganic compounds. and organic compounds with the assistance of bacteria as a catalyst and generates a generous quantity of current and are extremely suitable to be used as a transducer. MFC has 2 chambers anodic and cathodic and is separated by a proton exchange membrane. The fuel is changed by microorganisms within the anodic chamber and electrons and protons are generated. The charged particles are then moved to the cathodic chamber using an external electrical circuit and membrane. Among the chambers, these charged particles mix with gas to form water. These forms of biosensors are chosen for determining BOD and also measurement of water toxicity. The sensitivity is extremely low still as little power is generated. These microbial biological sensors have a wide range. Silicon-based microbial cell biosensors are developed for the identification of toxins in the water.[9]

4 ADVANTAGES AND DISADVANTAGES OF MICROBIAL BIOSENSORS

Enzymes are one of the foremost commonly used biological elements in biosensors. purified enzymes have many advantages, akin to higher effectuality for their substrates or inhibitors, however, their use in the fabrication of biosensors is restricted by time-consuming and expensive and tedious enzyme purification, and the necessity of multiple enzymes to get the measurable product and cofactors/coenzymes are needed. Microorganisms are appropriate and the best solutions for these issues. Microorganisms like bacteria and yeast are excellent candidates for developing microbial biosensors. As a result of microorganisms being additionally grown in immense quantities employing an easy and affordable culture procedure, analytical prices could also be lowered. alternative benefits of exploiting microorganisms in the development of microbial sensors embody the ability to find a large variety of target parts and also the ease with which they'll be genetically modified to provide genetically modified organisms with specific accelerator capabilities. microbial biosensors can work with efficiency in an exceeding variety of environmental conditions. Furthermore, because of their microscopic size and speedy development rate, microorganisms are capable of giving fast and relatively correct reactions to changes in conditions. Long investigations are another major application of microbial-derived biosensors. The use of some catalysts within the biosensor structure might inactivate them throughout isolation or immobilization, causing their molecular structure to be disrupted, though the usage of complete cells mitigates this matter. [10]

Microorganisms have many inherent and indispensable drawbacks just like the cells are genetically and phenotypically heterogeneous in nature, macromolecule synthesis system continues to be an understudy and hence the data is obscure and hypothetical, the sensitivity of the bioreceptor formed is low as compared to the enzyme biosensors, and conjointly these microbes can not be sterilized using heat because the biomolecules within would get denatured if multiple analytes are present the property can't have relied extensive analysis goes on during this field to overcome these drawbacks. The usage of whole-cell biosensors (WCB) for constant clinical analysis might be troublesome by the creation of a correspondent quality and quite a while stretching for cell multiplication.

5 APPLICATION OF MICROBIAL BIOSENSORS

5.1 Microbial biosensors in environment management and monitoring

Within the past few decades, pollutants and deadly compounds are increasing inside the atmosphere as a result of the overuse of chemicals in manufacturing facilities and various industries that brings many health problems to humankind and affects all living cells on the planet[11].Typical strategies like chromatography to detect these pollutants and toxins are very overpriced and time-consuming. As compared to alternative methods, microorganism biosensors are quick and easy, dependable, responsive, and cost-effective. For environmental monitoring in most cases, microorganisms are preferred. In soil monitoring microorganism biological sensors use microorganism species like *staphylococcus aureus*. The target analytes are serious metals and metalloids like copper, cadmium, zinc, and arsenic, organic xenobiotics like group sulfate, naphthalene, BTEX-benzene, toluene, ethylbenzene and xylene, nevertheless as physiologically active molecules and nutrients.[12] Microbial biosensors will even notice galactose, galactosides and provide necessary indications and knowledge concerning plant-microbe interaction. Antibiotic residues may be detected and known using microbially derived biosensors, preventing allergies, toxicologic effects, and so the emergence of antibiotic-resistant bacteria. The biosensors using prokaryotic microorganisms are much economical and in conjunction with that, the yeast-based biosensors similar to those with genus *Saccharomyces cerevisiae* are commonly used as these are vigorous, straightforward to be genetically engineered, and additionally encompasses a higher sensing approach for a eukaryote. These biosensors can sight toxic heavy metals like Cu2+, perishable organics, and endocrine-disrupting compounds (EDCs) once microbes act with heavy metals ions there are new developments caused by the small scale enzyme inhibition by the metallic charged particles, and these are used as a signal. A microorganism biosensor was developed to determine mercury using chlorella sp. which can be entrapped on a carbon surface. These sensors will even ensure the quantity of contamination once and before bioremediation. Methyl parathion is one of several pesticides that are heavily used in agricultural activities and are venturesome, not alone to insects but additionally to living beings[9]. Ethylene is nevertheless a new organic poisonous harmful compound which, additionally used as an organic solvent inside the manufacturing industries, can induce central nervous system damage. Microbial biosensors are created for the detection of compounds like phenol and nitrophenol with the help of *pseudomonas fluorescens.* In Europe and Japan, microbial biosensors are effectively utilized in water treatment plants and for evaluating biochemical oxygen demand for measurement of the standard of water and its reusability. Microorganism biosensors have applications like drinking water evaluation, underground water monitoring, and comprehensive study of soil and sediment extracts at highly radioactive to evaluate microbiologically influenced or induced corrosion (MIC) of metals in factories. A microorganism biosensor was created by incapacitated bacteria genus *pseudomonas sp*. extracted from unsound metal elements on an ethanoyl radical polysaccharide membrane. The respiratory organ activity of pseudomonas was calculated by mistreatment of the oxygen consumption rate.[13]

5.2 Agricultural industries

Microbial biosensors are utilized in the measuring of food processing parameters, detection of disease-causing harmful pathogens in crops and diseases in domesticated animals, detection and measuring pollutants and in addition nutrients in soil and crops, and so forth. Unwanted materials like harmful toxins are detected based on the inhibition of cholinesterase. Over time, the use of pesticides on varied crops has inflated quickly and has controlled the pest, however, these pesticides are contaminating the soil, water and additionally decreasing the nutrient quality of crops, and leading to bioaccumulation within the food chain. With the microorganism biosensors, toxins like organophosphates, ammonia, etc will be determined. Fungi attack farm animals and begin producing aflatoxin, which might cause serious complications and diseases like epithelial duct hemorrhage, liver damage, anorexia, then on, to sight these toxins an immunoaffinity fluorimetric biosensor is developed.[14]

5.3 Diagnostic and other medical applications

Microbial biosensors are a convenient, low-cost, and delicate diagnostic tool for detecting DNA, hormones, infectious pathogens[15]. These sensors can also be used again and have reduced labor and exaggerated the standard of treatments. These biosensors are usually accustomed to monitor aldohexose levels in diabetic patients.[16] In an amperometric-based microbial biological sensor for the identification of epinephrine, *Phanerochaete chrysosporium* ME446 the white-rot fungi was immobilized in gelatin with the assistance of a glutaraldehyde cross-linking agent on a noble metal electrode, where there' a modification from epinephrine to epinephrine compound there is production of a signal because of the increase within the current[17].DNA injury has many consequences and is incredibly damaging to the organism so *E.coli* SOS-EGPF is developed to search out DNA damage based on the SOS response.

These microbial biosensors could even be used for the identification of pathogens in domesticated animals like mycoplasma, salmonella, avian influenza viruses, then forth.[18]

5.4 Food and fermentation sector

The new way and diet cultures are inflicting the demand for high-quality food merchandise to extend each day, so microorganism based biosensors are a helpful and appropriate tool to substantiate the requirement and further make sure the standard as well as the correct pre-production of the raw materials and also the processing. The biosensors will confirm several food elements like carboxylic acid, phenolics acid, sugars ascorbic acid, amino acid, and also alcohol. Biosensors are often used for the identification and analysis of contaminants, allergens, toxins, pathogenic microorganisms and also determine the composition of raw components in food products. One of the earliest biosensors utilized in the food trade was for the measuring of glucose. *Pseudomonas* alcaligenes MTCC 5264 is immobilized on a plastic wrap membrane and it responds at a variety of 0.1 to one mg per milliliter inside some minutes. There's an optical biosensor that may confirm compounds like alanine, sorbitol, acetaldehyde, ethanol, saccharose then forth, a metabolizable product such as ethanol, urea, and macro and micronutrients such as vitamins, heterocyclic compounds such as carbohydrates, inorganic ions, amides, and alcohol may be measured thus they're utilized in numerous industries to regulate the fermentation method in making ready drink wine beer, etc. [19]

6. CONCLUSION

Microbial biosensors are a promising technology that has been with success applied in several fields. The commercialization of some chemical and optical microorganism biosensors developed for the environmental observance and different applications has occurred like BOD microbial biosensors from German firms like Isco GmbH, Groß Umstadt, and Spanish company Biosensors SL Moncofar. Lantronix Co., Ltd., Manchester, UK, developed the GreenScreen Environmental monitoring (EM) using a yeast cellular detector for the coincident determination of genotoxicity and cytotoxicity. However, because of the utilization of microorganisms and their non-specific cellular response analytes and complexity, there are some disadvantages such as slow response and poor selectivity. microbial biological sensors are getting more and more economical and reliable within the field of analysis and chemistry as biotechnology, micro, and nano-technology, and immobilization techniques have additionally evolved in past years. As advancements are happening in the sectors of biotechnology and recombinant DNA technology and genome sequencing becoming reliable and effective microorganisms are often genetically designed to upregulate or downregulate specific metabolic pathways and thus increasing the biosensor's property to individual analytes. Making microbial detector arrays is yet one more approach to strengthen the selectivity of microbial biosensors. The addition of the substance to be analyzed to the microbial sensor arrays can result in a unique response pattern. The target molecule will be recognized by coupling it with artificial neural network analysis. Due to their wonderful biocompatibility, amplified electron transfer property, and enormous surface area, nanostructured materials are utilized in biosensing as nanotechnology has improved. nanostructured electrodes are used with microorganisms immobilized on them, this will modify the response of microorganism biosensors positively. Within the laboratories due to the evolution and improvement in biotechnology and microtechnology microfabrication has become a routine task. Through the utilization of micron-sized electrodes in the development of single microbe-based devices can offer insight into how microorganisms react to specific targets, which has several promising applications in pharmaceutical analysis, clinical diagnostics, molecular and cell biology. The lab on chip technique where there has to be an integration of an organism onto a microfluidic chip for coming up with a biotic-microelectromechanical system. This method could also be a promising new part within the analysis of microorganism biosensors as those systems solely need low concentrations of analyte and supply favorable analytical characteristics resembling fast response and high accuracy. The whole-cell biosensors are being researched and are showing nice potential and have comprehensive positive effects and developments in the environment, food, medical and agricultural industry, and clinical diagnostics.

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