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Biosensors for Environmental Monitoring

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SUMMARY

Reliable monitoring of the substances in the air, soil, and particularly water is now necessary due to the expansion of environmental laws that restrict the discharge and concentrations of specific chemicals in the environment. Conventional analytical methods, while extremely accurate, have drawbacks such as high costs, a requirement for trained personnel, and a tendency to be laboratory-specific. Biosensors can offer distinct advantages in some circumstances due to their specificity, quick response times, low cost, portability, simplicity of usage, and continuous real-time signal. They are excellent for toxicological measures that are suitable for applications in health and safety because of their biological foundation.

INTRODUCTION

The rising quantity of potentially dangerous pollutants in the environment calls for rapid and cost-effective analytical techniques to be used in large monitoring programmes. The requirements, both in terms of time and price, of most classic analytical procedures (e.g., chromatographic methods) typically constitute a substantial hurdle for their regular application. In this setting, biosensors seem like potential alternative or complementary analytical instruments. The development of biosensors involves the immobilisation of the biological component at the transducer surface. The immobilisation procures both the stabilisation of the biomaterial and the closeness between the biomaterial and the transducer. Over the last 3–4 years, there has been an upsurge in the number of papers discussing biosensors for environmental monitoring, especially in the field of pesticide measures.

What is Biosensor:

It is defined as an analytical device, incorporating a biological or biologically derived sensing element (e.g. enzymes, antibodies, microorganisms or DNA), either intimately associated with or integrated within a physicochemical transducer (e.g. electrochemical, optical or piezoelectric transducers) and transform the biological data in to electrical signal. As per the International Union of Pure and Applied Chemistry (IUPAC), biosensor is a self-contained integrated device which is capable of producing specific quantitative or semi-quantitative analytical information which intercept the biological recognition element, *i.e.* biochemical receptor

Properties of Biosensor:

The ideal biosensor has two main properties that is sensitivity and selectivity. The biosensor components used in biosensor construction can be categorized in to two:

- Those were the primary sensing event result from catalysis (Enzymes, Microorganisms)
- Those depend on the essentially irreversible binding of the target molecules (affinity sensors based on antibodies or nucleic acids)

Segments of Biosensor:

The Biosensor consists of three segments: Sensor, Transducer, and Electrical circuit.

Sensor or Bio receptor: Sensitive element of biological origin that interacts with analyte and signal to change in its composition in electrical signal. These sensitive elements are developed for applying suitable biological engineering techniques (Koedrith et al.,2015)

Transducer or detector element: Physical component that amplifies the biochemical signal and the detector that alters the resulting signal into electrical and displays into an attainable way. It Works in a physico-chemical way to converts the signal in to interaction of the analytes,

Electrical circuit or signal processor: It is an associated part which consists of Signal Conditioning Unit, a Processor or Micro-controller and a Display Unit. It is Primarily responsible for the display of the results

Biosensor for BOD (Biological oxygen demand):
The biochemical oxygen demand (BOD) is one of the most widely used and standard tests in the measurement of organic pollution. Some conventional BOD tests require long incubation periods up to five days. The biosensors have made a significant commercial impact on environmental monitoring. There are several type of commercial BOD biosensors, with fast response times and automated sampling.

Electrochemical biosensor: It uses the oxygen-sensing electrode (e.g., Clark electrode) detect change in oxygen concentration (as a result of decomposition of organic pollutants by microbial film)

Amperometric BOD biosensor: It works with amperometric oxygen electrode transducer that detect the degradation or metabolization of microbial strains (Torulopsis candida,pseudomonas putida) for the measuresment of BOD

In-situ open type biosensor: The iBOB biosensor is a membrane-less device with an open-type anode. The two anodes, along with an Ag/AgCl-reference electrode with a double junction and a counter electrode, were placed in a pilot-scale aeration tank (1.2 m^3), and the anodic potential was controlled at a constant level using a potentiostat. The levels of current under both aerating and non-aerating conditions shows a logirthimic correlation of current with BOD concenteration

Biosensor for Heavy Metals:
The metals with density of (<5g/cm^3) is considered as heavy metals. The heavy metals like zinc, lead, mercury, cadmium, copper cause environmental pollution and is also known for high toxicity and bioaccumulation. The biosensors used for the monitoring of Heavy metals are:

Enzyme based biosensor: It works with urease immobilized biosensor by detecting urease enzymatic activity for the measurement of heavy metals

Bacterial biosensor: It works with specific genes for the dectection of heavymetals. Amaro et al.(2019) reported a whole-cell biosensor for the detection of heavy metals based on metallothionein promoters from *Tetrahymena thermophila.*

Optical biosensor: It detect lead (Pb) and cadmium (Cd) by the inhibition of alkaline phosphatase (AP) present on the outer membrane of microalgae (*Chlorella vulgaris*) used as a bioreceptor.

Biosensor for Nitrogen Compounds:
Inorganic nitrate ($NO3^-$) anion are present in natural and artificial environmental conditions Excess compounds can cause adverse effects on human health and contaminating the surface and groundwater which cause adverse effect on the aquatic environment. The biosensors used for the detection of nitrogen compounds are:

Electrochemical biosensor: It measures the accurate concentration of nitrate ions by using electrical communication between biological recognition element and signal transducer (electrode materials)

Conductimetric enzymatic biosensor: It works on the principle of enzyme based biosensor (cytochrome-c nitrate reductase) for the determination of nitate in a electrically linear range between concentrations of nitrite.

Nitrate ionization reactor – it measures the concentration of total nitrogen and converting nitrogen compounds from nitrites into nitrates.

Biosensor for pH:
pH sensors measure the level of pH in sample solutions by measuring the activity of the hydrogen ions in the solutions. The biosensors used for the detection of hydrogen ions are:

Fluorescence based biosensor: It detects the pH and oxygen and the sensor works on the principle of bacterial respiratory activity.

Fiber optic-based Sensor: It use the photic sensor and optical fibers etched with a fiber bragg grating(FBG) that produce light based signal to measure pH

Biosensor for Harmful Algal Blooms:

Microalgae is the major producers of biomass and organic compounds in the aquatic environment. The impacts of toxic algae species appear to have increased in frequency, intensity and geographic distribution for the public health and economic to minimise the damage to human health or living resources for efficient monitoring methods are required for monitoring potentially toxic algal species . The biosensors used for the detection of HABs are:

Nucelic acid biosensor: To detect toxic algae in the field, a portable semi-automated nucleic acid biosensor was developed in the ALGADEC project. This device enables the electrochemical detection of microalgae from water samples in less than two hours. The detection of the toxic algae is carried out on a sensor chip and is based on the so-called sandwich hybridisation technique

ALGADEC detection: It is semi-automatic device. The main steps are done automatically but filtering and a lysis procedure (digestion of the filtered material) has to be done manually . The core of the biosensor is a multiprobe chip - that can be used for the simultaneous detection of 14 different toxic algae plus two controls. Thus, it can be used to detect the species composition in harmful algal blooms.

Biosensor for Phenolic compounds:

Phenolic compounds are dangerous in the environment for a long period of time and their toxic effects cause adverse effect. Even a small concentrations (< 1 ppm) of Phenolics produce high toxicity accumulation in the environment that can be detected and monitored to protect the environment. The biosensors used for the phenolic compounds are:

Amperometric biosensor: It use enzyme (tyrosinase) as bioreceptor for the detection of phenolic compounds in the effluent water

Optical Detection sensors: It detects the phenol by visual inspection. For eg: sample with phenols can be detected by a proper probe to determine the absorbance changes linearly in the presence of different concentrations of phenolic then the colour changes occurs.

Enzymatic Biosensors: It determine the polyphenols, catechol, pyrogallol that inhibit the green indocyanine fluorescence in the presence of laccase and positively charged gold nanoparticles caused by polyphenols. This catalytic effect of the enzyme on the oxidation of the flurophore that detects the presence of a phenolic compound.

Biosensor for Pesticides:

According to Environment Protection Agency (EPA), “Pesticides are substances meant for attracting, seducing, and then destroying or mitigating any pest” under the class biocide. The biosensors used for the detection of pesticides are:

Inhibiton and catalytic based biosensor: It works by the hydrolytic activity of glutathione S-transferase enzymes to detect organo chlorine pesticides

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NA based biosensor: it uses the DNA probe that was hybridized with biotinylated and immobilized on an electrode surface binds with DNA target analyte (streptavidin). The presence of pesticides can be detected by unwinding of the DNA

Biosensor for Poly chlorinated biphenyls:

PCBs are the man-made persistent organic pollutants (POPs) with contains 1 to 10 chlorine atoms.they have unique properties like resistance to high pressure, temperature and chemically stable to acid and bases. The biosensors used for the detection of PCBs are:

Fluorescence-based technique – It is used for the detection of Polychlorinated biphenyls (PCBs) in water . It works on the principle of Benzopyrene (BaP) fluorescence These BaP forms hydrophobic complex in the presence of PCB

Advantages of Biosensor:

- large number of samples can be analysed in a relatively short period of time to reduce costs.
- Very low reagent usage –for calibration, maintenance of optimum conditions and sample dilution.
- Easy to use, durable
- Rapid, accurate, stable and sterilizeable

CONCLUSION

Biosensors can be used for environmental applications, genetic modification of enzymes and microorganisms and for the improvement of recognition element their immobilization and sensor interfaces. Biosensors are the biophysical devices for the detection of diverse environmental pollutants like phenolics, pesticides, toxins and hormones. Conventional analytical techniques such as gas chromatography and high pressure liquid chromatography are used to identify a range of pollutants, while biosensors can only detect at most one class of compounds

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