COMMENTARY

Recent advancements in the use of biosensors for the detection of bacteria and viruses in wastewater

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ABSTRACT

The presence of bacteria that cause disease in wastewater can be a useful diagnostic tool for infectious disorders. Biosensors outperform traditional methods for frequent infection screening and surveillance testing. They are quick, sensitive, and portable, with little risk of exposure in their detection techniques. This study describes the most recently developed biosensors for detecting bacteria and viruses in wastewater in this context. The assessment also includes information on improved detection methods for SARS-CoV-2, which has already killed over 4 million people. Furthermore, the paper emphasizes the possibility of on-line and real-time pathogen detection in wastewater pipes. Due to the intricacy of the matrix, the majority of the biosensors described were not intended for use with wastewater samples. This review, on the other hand, focuses on the performance parameters of recently created biosensors and analyses the role of nanotechnology in amplifying output signals, which boosts the accuracy and reliability of biosensors. Current research on the use of biosensors in wastewater offers a significant departure from the standard method in the field of medical screening.

Key Words: *Biosensors; Bacteria*

INTRODUCTION

Water shortage has become a serious issue in recent decades as a result of increased demand induced by population expansion and industrial development. While many locations throughout the world suffer from a lack of freshwater bodies and rely on alternate water supplies such as desalination, freshwater quality is worsening. Aside from population expansion, habitat encroachment, international travel, and globalization have resulted in the introduction of novel infections that might represent a serious danger to public health. Water contamination has resulted in a rise in toxins such as heavy metals, organic matter, and bacteria. Monitoring and detection techniques are required to identify suitable treatment processes before water is released or re-utilized. They are also an important aspect of Wastewater-Based Epidemiology (WBE) and are used to give data at the community level. Due to the worsening of water quality, WBE is a relatively recent method that analyses the presence and amount of contaminants and biomarkers in wastewater. In contrast, conventional detection technologies often identify infections based on particular elements and are frequently employed to give data at the individual level. Despite the numerous changes made to traditional methods over the years, they always fall into one of three categories: quantitative Polymerase Chain Reaction (qPCR), culture-based methods, and immunology-based approaches. These traditional analytical methods are recognized for their great sensitivity, selectivity, and stability; but, their expensive cost and laboratory requirements may restrict their wide utilization, particularly in jurisdictions with limited resources.

The quick identification of pathogens in wastewater might considerably assist infection control. Pathogen-causing infectious illnesses spread via several channels, making it challenging to manage newly developing pathogens such as the SARS-CoV-2 virus. Recent research has shown that the virus may be identified in the faeces of infected people using qPCR. As a result, WBE is a promising approach for tracking the COVID-19 epidemic. Currently, qPCR remains an effective tool for COVID-19 testing, despite the danger of exposing those doing the tests to the virus. While social separation and isolation are likely to suppress the present pandemic, the breakout of this illness has already surpassed SARS and is projected to return in numerous waves of infections. The most efficient method of detecting such infectious illnesses is by mass testing and adequate isolation and treatment. The incorporation of biosensors into wastewater systems might allow mass testing while also ensuring adequate separation and treatment to a far greater extent than current detection methods.

Biosensors for the detection of biomarkers in wastewater, such as inorganic ions, organic contaminants, medicines, and pathogens, have previously been created. Inorganic ions are frequently present at extremely low quantities in wastewater, which necessitates more research and validation before inorganic sensors may be widely employed. Biosensors for organic contaminants and medicines, on the other hand, have been extensively researched, with sensitivities that are more suitable than those of inorganic biosensors. There are now a rising number of research being conducted on the development of biosensors for disease detection. At the same time, research on biosensors for pathogen detection in wastewater is still in its early stages, indicating the need for more study. The biological receptor is an essential component of these biosensors. Whether the target molecules are human nucleic acids, peptides, proteins, or antimicrobial resistance indicators, the biological receptor is a crucial component that defines a biosensor's selectivity and Limit of Detection (LOD). An antibody, enzyme, cell, microbe, or nucleic acid aptamer might be the biological element. In general, optimizing a biosensor entails selecting a biological element that interacts with the target analyte from a given sample while giving fast and reliable output. According to studies, despite their high cost and detection time, nucleic acid aptamers have the highest affinity for target molecules. Antibodies, on the other hand, continue to be the gold standard biological components due to their great selectivity, affinity, and regeneration for diverse pathogens. Aptamers, antibodies, enzymes, and microbes are the most often described biological receptors.

Because of the existence of a complex wastewater matrix, it is vital to consider the accuracy of the biosensor detection of pathogens in wastewater, and thus it is important to optimize the manufacturing parameters to improve the biosensor response. Nanomaterials are frequently utilized to improve the sensitivity of biosensors, particularly when the biosensor's applicability is expanded to real-world samples. When introducing nanomaterials into the realm of biosensors, it is critical to evaluate their affinity for biological receptors. Carbon nanotubes (CNTs), for example, which have been widely employed in biosensors due to their excellent electrical characteristics, do not exhibit affinity for biological receptors. As a result, it is critical to incorporate linking molecules to immobilize receptors on the surface of nanomaterial-based biosensors. When nanomaterials are functionalized with bio receptors such as enzymes or antibodies, a biochemical reaction occurs upon binding to specified biological molecules or proteins, as with most biosensors. Such reactions create electrical alterations in the medium, which serves as a detecting indicator. The electrical characteristics of nanoparticles influence

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the strength of the induced electrical changes significantly. As a result, the introduction of nanomaterials into the field of bio sensing has cleared the way for the development of more sensitive biosensors. Exploiting such unique features has propelled nanomaterial-based biosensors to compete with, if not outperform, conventional detection techniques. The next sections examine recently developed biosensors for detecting bacteria and viruses, with a particular emphasis on the newly developing SARS-CoV-2.

As the presence of some microorganisms in wastewater might be dangerous, it is important to treat wastewater properly. However, especially in underdeveloped nations, it is critical to recognize the efficacy of genuine treatment plants. Several efforts have been made to assess the effectiveness of wastewater disinfection procedures such as chlorination, ozonation, and Ultraviolet (UV) irradiation. UV irradiation was shown to be successful in removing the virus from treated wastewater in the instance of SARS-CoV-2. SARS-CoV-2 has a unique genetic structure that promotes its degradability in the presence of UV light, which may not be true for other viruses or dangerous bacteria. As a result, these approaches can be ineffective against various bacteria at times, which is why monitoring programs remain extremely helpful for identifying harmful elements in wastewater despite the use of disinfection technologies. The employment of biosensors, rather than traditional approaches, might considerably improve the continuous monitoring of pathogen-causing illnesses given by surveillance systems.

CONCLUSION

Pathogens provide an ideal opportunity for monitoring since they are frequently present in wastewater via faecal excretions. In the case of SARS-CoV-2, conventional procedures are still regarded the gold standard for screening, with a clear emphasis on PCR. Recently developed biosensors for the detection of bacteria, viruses, and SARS-CoV-2 were reviewed in this paper. These papers did not broaden the scope of their study to include pathogen identification in wastewater samples. This is because dealing with complex matrices in wastewater is challenging. Furthermore, studies demonstrate that biosensors perform better when tuned and combined with nanomaterials. As a result, it is suggested that the focus of study be moved to bio sensing of pathogens in wastewater rather than conventional detection technologies. When incorporated into wastewater or sewage systems, this gives a possible possibility for the application of biosensors in online and real-time detection, which might revolutionize the area of screening for presently existing and developing infectious illnesses.