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Review

Advances in Biosensor-Based Instruments for Pesticide Residues Rapid Detection

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The food safety issues associated with the presence of pesticide residues in agriculture products have raised the need of pesticide residues detection instrument to detect pesticide residues rapidly, sensitively and online in different commodities. The measurements of specific biological-recognition that coupled with a signal transducer were the principle to realize the detection. Instruments based on biosensors for pesticide residues detection have shown advantage and broad application prospects in the instrument market. The present overview is an effort to review the various transduction systems and biosensor devices so far in the development of pesticide residues rapid detection instrument based on biosensors, such as electrochemical biosensors, optical biosensors and mass-based biosensors. Furthermore, miniaturization, stability, sensitivity, repeatability and signal intensity of the biosensors and applications of these biosensors were evaluated in the development of biosensor instruments. Recent advances about pesticide residues detection with different types of biosensors have been analyzed and summed, which was shown that with the development of biosensors for detection monitoring, corresponding biosensor instruments are also becoming one essential tool in society with low cost and to make the pesticide residues detection foolproof.

Keywords: Biosensor, Instruments, Pesticide residues, Rapid detection, Signal transducer

1. INTRODUCTION

During vegetative growth of grains, chemical plant protection is used to protect against the harmful impact of pests, pathogens, and weeds [1]. Pesticides have played an important role widely used in preventing or reducing losses by pests, weeds and diseases and thus can increase farm production [2]. The use of organochlorines (OC) and organophosphorous pesticides (OPs) which were main types of the pesticides categories may cause pesticide residues in the environment and food chain [3, 4].

However, since these pesticides act through inhibition of acetylcholinesterase (AChE), they also represent a risk to human health. For several years, some researches have shown that excessive exposure to pesticides can lead to various diseases [5, 6]. Rapid detection of pesticides was more and more necessary due to their toxicity, persistence and stability [7]. The implications of pesticide residues for human health and the environment were reviewed in the literatures [8-10]. Therefore, for the sake of food safety and environment protection, it is of great importance to find ways to rapidly estimate the level of grain contamination with pesticide residues and the risk these residues pose to human and animal health [11–13]. For this reason, the detection technology and method of pesticide residues remaining on the food were described [14-17]. Numerous analysis methods such as gas chromatography–mass spectrometry (GC–MS) [18-20] and liquid chromatography–mass spectrometry (LC–MS) [21-23], capillary electrophoresis (CE) [24-26], flow injection immunoanalysis and fluorimetry [27] have been developed for pesticides residues detection. The QuEChERS [28-30], pressurized liquid extraction (PLE) [31, 32] and liquid–solid extraction (LSE) [33, 34] were mainly used concerning the extraction procedure for pesticides which have been described and reviewed extensively in the literatures [35, 36].

Regarding pesticide residues detection, GC and LC are commonly utilized [37, 38]. These chromatographic techniques have been coupled to mass spectrometry such as GC–MS and LC–MS [39, 40]. QuEChERS and CE–MS/MS could be a potent combination for halosulfuron-methyl herbicide detectionin food [41-44] GC, LC, GC-MS and LC-MS/MS were traditional detection method for pesticides residues detection [45-47]. Although these methods could realize the quantitative analysis at the same time, they have their own advantages and shortcomings, such as laborious, slow and expensive. The disadvantages limited their application in rapid detection and field applications [48]. Moreover they were complicated to operate and were not suitable for on-site and in-field Detection [49]. Therefore, there is a need in developing a good method to realize the rapid detection. The development of biosensor-based instruments for pesticide residues rapid detection is probably one of the most promising ways to solve these problems mentioned above. Some recent literatures reported the answers to these needs [50-52].

We reviewed the literatures of the past years and concluded that the biosensors could be used for pesticides rapid detection with a good stability and repeatability [53-54]. As a new analytical method, biosensor could be widely used in the determination of food contamination [55]. Biosensor techniques based on the principle of specific biological-recognition have shown satisfactory results for environmental control, food quality monitoring and toxicity detection in recent years [56–58]. All these detection methods based on biosensors were shorter time response and lower cost comparing with the traditional method, but these methods were not enough convenient to use, moreover, complex detection procedures make them unsuitable for commercial and industrial applications [59]. Biosensors as a kind of signal trigger couldn’t get the detection results of pesticide residues directly, the acquisition signal would convert into detection values after signal collecting and accessing. With the development of related technologies, the combination of biosensor technology and existing application technology had prompted the emergence of the rapid detection devices for pesticide residues. These biosensor-based instruments were designed to improve the existing detection methods, such as GC and GC/MS by simplifying complex and tedious preparation, thus cutting costs and saving detection time cost [60].

The instruments for pesticide residues detection based on biosensors integrated the signal trigger, signal converter, signal processor and peripheral function expansion module and could realize the rapid detection of pesticides residues on food with automatic data processing, display, print out and data storage. The biosensor-based instruments and devices for pesticide residues detection would be the development direction of biosensors for detection of pesticide residues and suitable for industrial or commercial applications [61-63].

2. CLASSIFICATION OF BIOSENSORS

Biosensors applied biological elements to be an integrated electronic device and these biological elements could bereceptor proteins, nucleic acids, cells, antibodies, enzymes and tissue sections as the analysis medium. In order to realize signal detection, a biological recognition element was coupled to the biosensor for signal detection to a transducer, (Fig.1.) which can be finally displayed on a panel of biosensor-based instrument after signal processing and amplification. The combinations of biological molecules with electronics have played an important role to further developments in biosensors [64, 65].

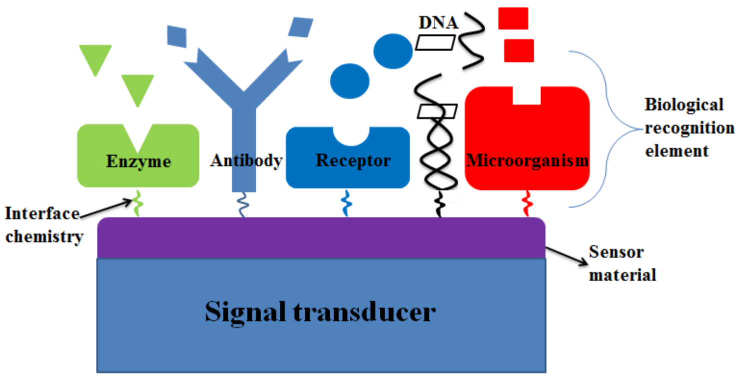


Figure 1. Schematic representation of biosensors

According to the biological-recognition element or the transducing system used, the biosensors that can be classified into different types. Depending on different kinds of biological-recognition element, biosensors can be classified into enzyme-based biosensor, immunosensor, cell-based biosensor, microbial biosensor, biomimetic biosensor, phage-based biosensor and so on [66]. The biosensor's selectivity and specificity were based on the biological-recognition element which was greatly influenced by the transducer. Biosensors can be further classified into optical biosensor, mass-based biosensor and electrochemical biosensor based on the transduction mechanism. Electrochemical biosensors also can be classified into amperometric, potentiometric, conductometric and impedimetric biosensor according to the properties of the output signal got from transducers (Fig.2.). The pesticide residues detection instrument based on biosensors was one of the currently hot research fields which complied with the requirements of the rapid and sensitive detection technology.

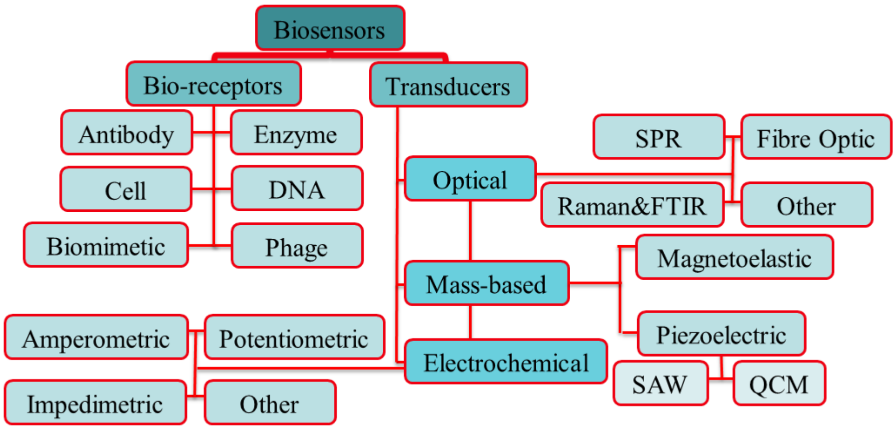


Figure 2. Classification of biosensor

3. BIOSENSOR INSTRUMENTS FOR PESTICIDE RESIDUES DETECTION

A biosensor is an instrument which combining a transducing device with a recognition element. These instruments had something in common, such as the support material, which the recognition element were immobilized on. The recognition element may be an antibody/antigen pair, an enzyme and its substrate, a receptor and its specific ligand, or even an analyte and living cells that binds to them specifically. The specific interactions between the target analyte and biological-recognition element may produce physiochemical changes, these changes were measured and detected by the transducer. The biochemical signal would be processed into an analog or digital electronic signal by transducer. The concentration of the analyte could be got from the proportional relation between analyte concentration and signal strength. Based on this principle, the quantitative detection of pesticide residues could be realized. (Fig3).

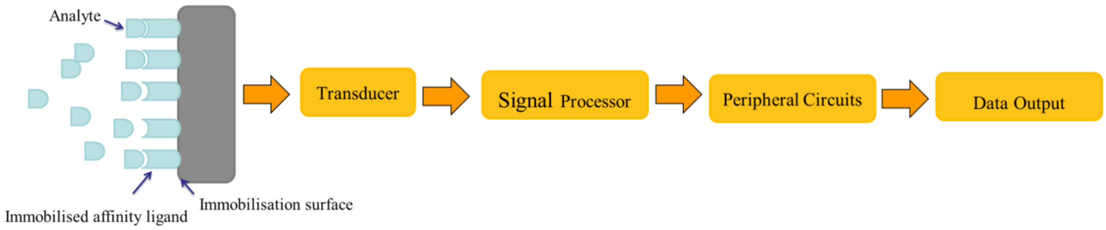


Figure 3. The basic configuration of a biosensor.

Over the last decade, more and more detection instruments based on biosensors were described in the literatures, such as the pesticide residues detection instruments. Most biosensor instruments reported to date are utilizing different detection principle. Based on the transduction mechanism, biosensor-based instrument could be further classified into electrochemical instrument, optical instrument and mass-based biosensor instrument as described in the following sections.

3.1 Detection Instruments Based on Electrochemical Biosensors

For a long time, many approaches have appeared developing new affinity biosensors for pesticides, especially electrochemical biosensors. Electrochemical biosensor is one of the most widely used biosensors and also the most common methods used in biosensors. More and more electrochemical biosensors were used for pesticide residues detection, which was effective and easy to implement. Moreover, electrochemical biosensor could provide the portable and miniaturization design for the biosensor-based instrument. Electrochemical biosensors output electrical signals through the transducers, such as potential, current, conductance, or impedance caused by the electrochemical reaction or immunoreaction. The pesticide residues detection instrument based on the electrochemical biosensors can determine the level of pesticides by measuring the change of potential, current, conductance, or impedance caused by the electrochemical reaction or immunoreaction. According to the signal property, electrochemical biosensors can be mainly divided into three classes. These classes are: (1) amperometric biosensors, (2) potentiometric biosensors and (3) impedimetric biosensor as shown in Fig. 4 [66].

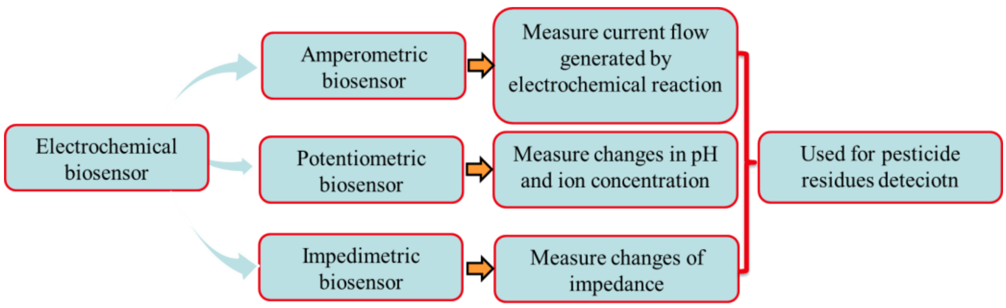


Figure 4. Classification of different electrochemical biosensors.

Recent frontier research on the rational design of pesticide residues detection instrument, coupled with electrochemical analytic methods, has led to advances in electrochemical biosensor applications. Besides these works, signal processing technology, electronics and information technology and instrument development technology have been used to analyze various pesticides in the food and environment applications, including methyl parathion [67], carbofuran [68], paraoxon [69], thiodicarb [70], methamidophos [71], chlorpyrifos [72], etc.

3.1.1 Detection Instruments Based on Amperometric Biosensors

Amperometric biosensors instruments realize the pesticide residues detection by measuring the change of current induced by the specific reactions between biological-recognition element and analyte, such as enzyme and substrates. Among electrochemical biosensors, the enzyme activity could be employed to indicate the levels of the pesticide residues by combination of electrochemical methods with the enzymatic reactions. Amperometric enzyme biosensors have shown satisfactory performance for pesticides analysis [73, 74]. The principle of amperometric enzyme biosensor used for detection was based on the changes in the activity of enzyme composure to the pesticides before and after. The oxidation current of choline would be produced and processed by signal sampling and processing module of the instrumentafter enzymatically catalysed hydrolysis of substrate.

Ascorbate oxidase based amperometric biosensor was used for OP pesticide ethyl paraoxon detection based on the inhibitory effect of pesticides to ascorbic acid oxidase activity. The proportional relation between the inhibition ratio of the enzyme substrate reaction and the pesticides concentration was in the range 1–10 ppm, the regression value of this linearity curve was 0.9942 [75]. An amperometric microbial biosensor used to measure OPs was presented. Experimental results show that the limit of paraoxon detection was as low as 0.2μM and the limit of methyl parathion detection was 1μM, which both with very good performance [76]. Recent research has also focused on utilizing many new types of carbon nanomaterials [77] on the amperometric acetylcholinesterase (AChE) biosensors [78]. Multiwalled carbon nanotubes [79], nanowire electrodes [80], ionic liquids-AuNPs-porous carbon [81], amino functionalized carbon nanotubes [82], NiO nanoparticles–carboxylic graphene–nafion [83], multiwall carbon nanotubes onto liposome bioreactors [86], carboxylic graphene coated with silver nanoparticles [87] and ionic liquid functionalized graphene–gelatin-modified electrode were used on the AChE biosensors which worked well for pesticides detection. Table 1 provides a performance comparison of biosensors based on immobilized AChE.

Table 1. Performance comparison of biosensors based on immobilized AChE.

Sample	Electrode	Linear range (mM)	Detection limit (mM)	References
paraoxon	AChE/poly(SNS-NH_2)/f-MWCNT/GE	0.05-8.00	0.09	[79]
carbaryl	AChE/IL-GR/Gel/GCE	10^{-11}-10^{-5}	5.3×10^{-12}	[60]
chlorpyrifos	NF/AChE–CS/AgNPs–CGR–NF/GCE	10^{-10}-10^{-5}	5.3×10^{-11}	[85]
dichlorvos	AChE/(MWCNTs/ALB)n/GCE	0.25×10^{-3}-$1.75\times10^{-3}$and 2.00×10^{-3}-10^{-2}	0.28×10^{-3}	[84]
methyl parathi	NF/AChE-CS/NiO-CGR-NF/GCE	10^{-10}-10^{-7}	5×10^{-11}	[83]
paraoxon	AChE/CNT–NH_2/GC	0.2×10^{-6}-0.3×10^{-4}	0.08×10^{-3}	[82]
dichlorvos	AChE/[BSmim]HSO_4-AuNPs-porous carbon/BDDE	4.5×10^{-10}-4.5×10^{-6}	2.99×10^{-10}	[81]
phoxim	AChE/ZrO_2 /CHIT/GCE	6.6×10^{-3}-0.44×10^{-3}	1.3×10^{-3}	[172]

A biosensor-based detection system was designed by Xia Sun, Xiaoxu Sun, etc. This system based on amperometric AChE biosensor to realize the rapid detection of chlorpyrifos in fruits and vegetables. This system was consists of three electrode system, double integral analog to digital (A/D) circuit, potentiostat and differential amplification circuit modules. The concentration of chlorpyrifos could be got from the proportional relation of concentration and inhibition ratio. Inhibition ratio would get from the oxidation current generated by hydrolysis reaction between AChE and substrate (acetylthiocholine chloride). The schematic drawing of this system was shown in Fig.5. The microchip played an important role during the instrument detection. This system can realize the on-site detection based on the electrochemical reaction with a good performance during the real samples detection [86, 87].

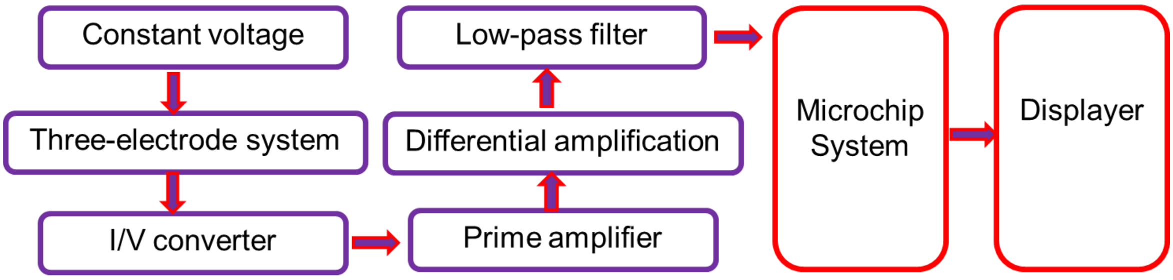


Figure 5. The schematic drawing of designed detection system based on the microchip

Tova Neufeld, Inna Eshkenazi, et al. presented a micro flow injection system using screen-printed electrodes modified by an enzymatic membrane, as shown in Fig.6. This system could realize the trace detection of OP. The detection results could be got from the inhibition of AChE by the enzymatic reaction [88].

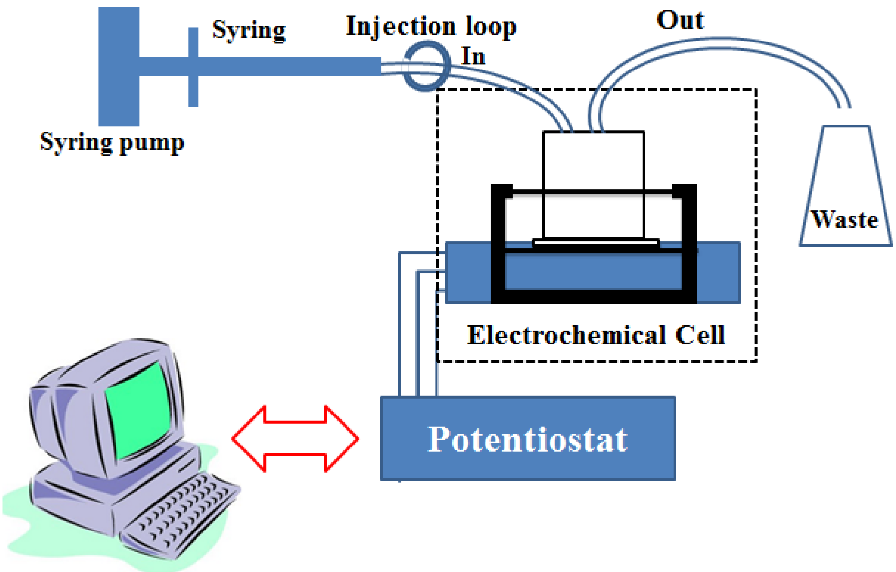


Figure 6. The schematic diagram of the flow system

3.1.2 Detection Instruments Based on Potentiometric Biosensors

The detection principle of the Potentiometric devices was based on the measurement of pH and ion concentration from the immunoreaction between an antigen and an antibody which immobilized on a working electrode. The specific binding of antibody and antigen would cause the change of the potential difference between the electrode bearing the antibody and a reference electrode. The detection of analyte could be realized by the function of the potential difference and concentration [66]. Recently, more and more polyclonal antibodies and monoclonal have been used on the biosensors. These researches have greatly facilitated the development of detection instruments based on potentiometric biosensors for pesticide residue detection [89-90]. A potentiometric biosensor based on monoclonal antibody for terbuthylazine detection was presented. The combination of light addressable potentiometric sensor and highly specific monoclonal antibody was a major innovation of this potentiometric biosensor. [91].

The potentiometric biosensor used for pesticides residues detection was developed during the past years. The enzyme electrode of this potentiometric biosensor was a pH electrode and this electrode mentioned was modified with an immobilized organophosphorus hydrolase (OPH) layer formed by cross-linking OPH with bovine serum albumin (BSA) and glutaraldehyde [92]. Examples of these kinds of biosensors instrument system for pesticides residues detection have been reported [93, 94]. Joseph Wang, Robin Krause, et al. described a flow-injection system with dual amperometric and potentiometric OPH biosensors for the simultaneous and rapid detection of OP compounds. The flow-injection system was shown in the Fig. 7. The improvement and development of this system was the simultaneous use of amperometric transducer and potentiometric transducer [95].

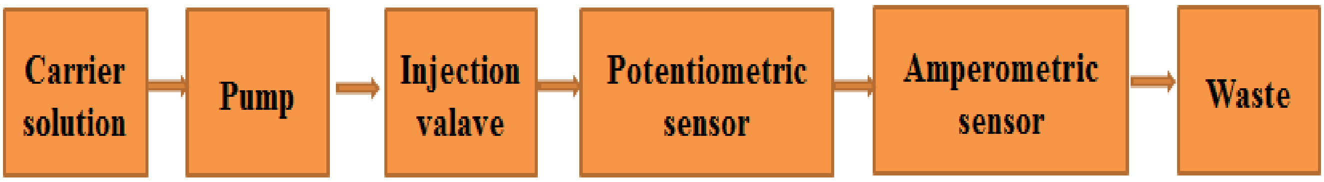


Figure 7. Schematic diagram of the dual-biosensor flow-injection system

The core of the potentiometric biosensor design was the ability to trigger and capture the effective and stable potential signal. This type of signal can be triggered by the enzyme catalytic reaction and the immune reaction of antigen and antibody [96-100]. In order to improve the stability and the amplification factor of the electrical signal, a lot of relevant theoretical researches were carried out [101-104]. These studies have effectively improved the identification of pesticide molecules on the biosensor and the detection precision of pesticide residues. With the development of electronic technology and other related technology, the combination of theoretical research and application research of biosensors will be a strong impetus to the application of biosensors in pesticide residues detection.

3.1.3 Detection Instruments Based on Impedimetric Biosensors

Impedance biosensors were one of the most widely used biosensors. They had great advantages compared with weak current signal processing got from the transducer for the design of biosensor-based instruments for pesticide residues rapid detection. Impedance biosensors were widely used as analytical technique that provides trace pesticides residues detection with a good performance [105, 106]. Among of the different kinds of biosensors, impedance has been used for several decades [107-111]. With the development of the biosensor, the detection instruments based on impedimetric biosensors had a great prospect of application [112-114].

Detection instruments based on impedimetric biosensors have been successfully used to detect pesticide residues [115-117]. A design of portable pesticide residues detection instrument was presented based on an impedance immunosensor by Jiang Ding, Xia Sun, et al. The immunosensor exploited the novel multilayer films based on Au nanoparticles (AuNPs) and polyaniline/carboxylated multiwall carbon nanotubes-chitosan nanocomposite. The detection principle of the instrument was based on the electrochemical characteristic of antigen-specific antibody immune response. With a stronger signal generated from the antigen-specific antibody immune response, the signal detection circuit was designed more easily. They integrated immunosensor and signal detection circuit to fabricate pesticide residues detection instrument. The process of impedance detection could be realized in this way: firstly, the impedance signal strength was changed when antigen-specific antibody immune response had happened. Secondly, AD5933 generated excitation signal which applied to the test impedance, and collected response signal. Thirdly, digital processing DFT module outputted the result to microcontroller. Finally, the microcontroller would compare result with the previous impedance value and get the difference. Compared the rate of change with the standard curve, the microcontroller would output the conclusions about pesticide concentration. The LCD screen would display the detection result and microcontroller played an important role during the detection procedure. The schematic drawing of this detection system was shown in Fig.8. This proposed instrument could realize the rapid detection of pesticide residues in fruits and vegetables with automatic data processing and presented the result on the spot. The impedance test error was less than 5%. The results showed that the proposed instrument had a good consistence compared with the traditional analytical methods [118].

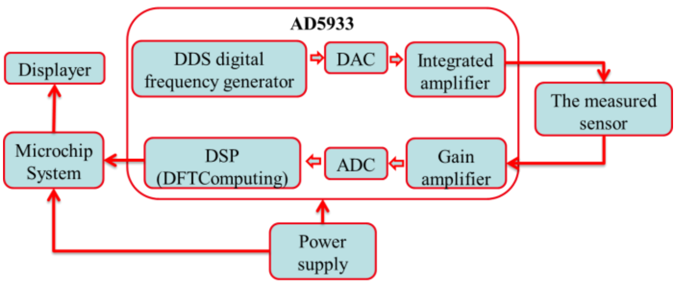


Figure 8. Schematic drawing of detection device structure.

In some cases, the current signal and potentiometric signal got from biosensors were very weak [119-122]. These weak current signal and potentiometric signal were processed, such as signal amplification and signal filtering, in order to extract the useful detection information from the weak electrical signal. The process of signal processing may introduce other unknown disturbances which may hinder the extraction of useful information, the impedimetric biosensors were designed to overcome it.

3.2 Detection Instruments Based on Optical Biosensors

Optical biosensors were powerful detection tools and they were widely used in food industry, medical field and environmental monitoring [123]. Optical biosensors are particularly attractive for pesticide residues detection [124-126]. The combination of target analyte and receptors which immobilized on the transducer surface would lead to a change in refractive index or thickness would change, these diminutive changes could be detected based on optical biosensors and spectophotometric. According to chemical-physical phenomena, different optical biosensors could divide into absorption, fluorescence and surface-plasmon resonance (SPR) and so on [127-129].

3.2.1 Fluorescence detection

Fluorescence is an emission phenomenon in which a fluorophore absorbs light or electromagnetic radiation and emits light at visible range. Sometimes, the emitted radiation may be at shorter wavelength or at the same wavelength than the excited radiation. The latter is called resonance fluorescence. Since it is accompanied by loss of radiative energy, the fluorescent light is always at a longer wavelength than the absorbed light called stokes shift [130, 131]. A high-throughput fluorescence polarization immunoassay was used for OPs detection, the detection limit of the OPs was 10ng/ml [132]. A pH-sensitive fluorescence probe has been reported to detect organophosphate and carbamate pesticides which had a lower detection limit [133]. Further simultaneous detection been possible using a probe for fluorescence detection was developed to detect azinphous ethyl, malathion and heptachlor pesticides [134]. The detection of OPs and chemical warfare agents based on a fluorescence-based biosensor has been reported by L. Viveros, S. Paliwal, et al [135]. Reports of using broad-specific single-stranded DNA based fluorescence polarization aptamer assay for organophosphorus pesticides detection have surfaced [136]. A simple and sensitive fluorescence biosensor using H_2O_2-sensitive quantum dots/bi-enzyme to OPs has been reported, the limit of detection (LOD) for dichlorvos is found to be 4.49 nM [137].

3.2.2 Surface Plasmon Resonance Instruments

The SPR was a device applied biosensors and optical transducer element for environmental and food safety monitoring [138, 139]. SPR occurs when polarized light illuminates, under conditions of total reflection, a thin conducting film at the interface between two transparent media with different refractive indexes. It involves the capture of photons by free electrons in the film, and it results in reduced reflection at a specific angle, called the SPR angle (θ), which depends on the refractive index near the biosensor surface that is altered by affinity-pair interaction at that surface (Fig.9). Concentration changes could be detected by the refractive-index changes. SPR Instruments could be used for pesticides residues in crude samples by their good performance [140].

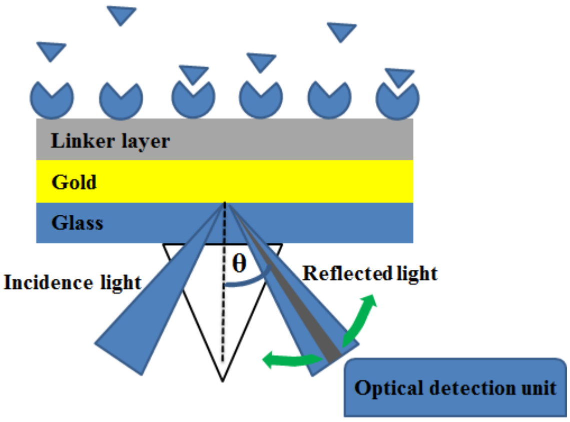
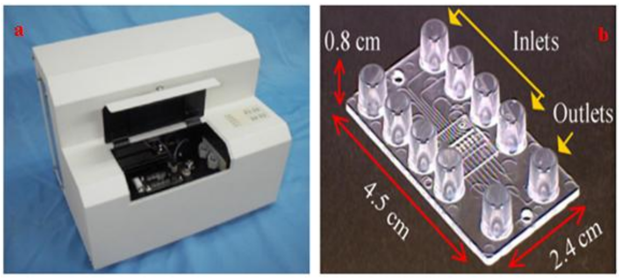


Figure 9. Biosensor based on SPR principle. SPR response is a measure of changes in the resonance angle (θ).

SPR-biosensor technology has developed for a long time and has applied in different areas, such as environmental area, food industry [141-144]. A novel miniature SPR immunosensor equipped with all-in-one multi-microchannel sensor chip for detecting low-molecular-weight analytes was described by Sook Jin Kim, K. Vengatajalabathy Gobi, et al. This multichannel SPR sensor system was composed of a portable SPR instrument (Fig.10a) and a multichannel flow-cell module (Fig.13b) [145]. The development of SPR sensor system is presented as a remarkable worthy method for the detection of pesticides residues [146-151]. One example was that SPR quantitative analysis of direct detection of atrazine traces on Au-nanoparticles was described by Xia Liu, Yang Yang, et al. In this work, they have demonstrated that small molecule atrazine in low concentration can be directly detected via antibody–antigen recognition using SPR biosensor with AuNPs of 30.35 nm diameter served as sensor elements [152].



(a) (b)

Figure 10. (a) SPR instrument (b) multi-microchannel sensor module

3.3 Detection Instruments Based on Mass-based Biosensors

Detection instruments based on mass-based biosensors based on recording the minuscule changes on the probe or transducer surface. Any change in mass due to binding of chemicals to surface of crystals can be detected by change in resonance frequencies of crystals [153].

3.3.1 Piezoelectric method

The piezoelectric effect occurs in crystals without a center of symmetry [154]. When pressure was applied to the crystal, the dipole moment arises in the molecules of the crystal. [155]. A piezoelectric biosensor was used to detect phoxim and chlorpyrifos in radishes has been reported. Their detection results have shown that the biosensor possesses similar performance with GC, and has a great potential for pesticides residues rapid detection [156]. Mingfei Pan, Lingjie Kong, et al. developed a piezoelectric immunosensing platform based on multi-wall carbon nanotube(MWCNT)-poly (amidoamine) dendrimer, this platform had a good performance for metolcarb detection, the linear range was 0.1–50.0 mg L^{-1} and the detection limit was 0.019 mg L^{-1} [157]. A piezoelectric quartz crystal (PQC) biosensor based on molecularly imprinted polymer (MIP) has been developed for pirimicarb detection in the samples of contaminated vegetables [156]. Micro-electromechanical system and Quartz crystal microbalance (QCM) as versatile biosensors have be widely used in recent years, demonstrating high sensitivity and label-free detection. [159].

Piezoelectric effect was the basis of QCM. QCMs were used for the pesticide residues based on the mass deposited on them which decrease the resonant frequency of the QCM. The principle of QCM for pesticides residues detection was based on measuring the decrease in the resonant frequency of the QCM. QCMs were very sensitive due to the changes of frequency could be detected precisely [160-162]. The QCMs could detect amounts of deposited material with an average thickness of less than a single atomic layer [163-166].

3.3.2 Magnetoelastic method

In recent years, magnetoelastic biosensors have been used in various applications. The magnetoelastic thick-film was main component of the magnetoelastic biosensor. This magnetoelastic thick-film coupled with a chemical or biochemical sensing thin film. The response to an externally applied time-varying magnetic fieldwas magnetoelastic ribbon vibrates mechanically with a characteristic frequency [167, 168]. Many magnetoelastic biosensors have been developed for pesticide residues detection [169, 170]. Pengfei Pang, Yanli Zhang, et al. have developed a methodology for novel magnetoelastic biosensing applications based on the biocatalytic precipitation of an insoluble product [171].

4. FUTURE TRENDS

4.1 Miniaturization and Integration

The miniaturization of the instrument is a big trend in the development of the various kinds of biosensor instruments. Compared with the large-scale analytical instruments, such as GC, LC, GC–MS and LC–MS, etc. the detection instruments based on biosensors were designed to realize the rapid and on-side detection of pesticide residues. Thus, in order to meet the needs of current application requirements, the portable design of pesticide residues detection instrument is a trend of the future development of biosensor-based instruments. In order to meet the portable design of instrument, the detection system needs to be integrated design which was used for converting electronic responses for each analyte into meaningful concentration data. Furthermore, miniaturization of biosensor instruments not only reduces the size of detection device and integrates all steps of the analytical process into a single-sensor device, but also reduce the difficulty of experiment technology and the requirement of experimenter.

4.2 Multichannel Detection

In the actual detection, the instrument needs to detect a large number of actual samples, thus, the detection instrument is designed to be capable of achieving multichannel detection, which in order to improve the detection efficiency effectively. The multichannel SPR sensor system and screen-printed, biosensor array, etc. can achieve multichannel detection. The realization of multichannel detection needs to be realized in many aspects such as biosensors and instruments.

4.3 Wireless Communication

With the development of big data and the internet of things, the construction of intelligent agriculture is a hot topic. The biosensor-based instruments which have functions of pesticide residues rapid and on-side detection provide the possibility of detection information sharing. The biosensor-based instrument with a wireless communication module can transmit the detection information to the receiving end in real time. In addition, through the big data and internet of things to achieve the effective analysis, processing and sharing of detection information.

4.4 Stability and Repeatability

The output of the biosensor are weak electrical signal, the obtainment of the accurate signal is the premise to obtain the accurate detection results. In the actual detection, there are a variety of interference factors, including in the samples and detection environment, thus, signal processing and anti-interference design are crucial for obtaining accurate results. At present, the study on the electrochemical modification of the biosensor, the pretreatment of the sample and the weak signal processing will be effective to improve the stability and repeatability of the detection.

5. CONCLUSIONS

In this article, we reviewed the most recent literatures on biosensor-based instruments development for pesticide residues detection using a transduction-based classification. Instruments based on electrochemical biosensors, optical biosensors and mass-based biosensors are strong candidates for screening pesticide residues and they become more and more relevant in environmental and food analysis. Biosensor-based instruments remain the preferred technique for qualitative and quantitative detection of pesticides. Compared to chromatography and other methods, the advantages of biosensor instruments can be described as follows: Compared with the traditional analytical instruments, such as GC, etc., ⑴biosensor-based instruments are selective and sensitive for pesticides detection. ⑵The biosensor-based instruments were simple to operate with lower cost and less time. ⑶After further design and improvement, they can be used for field detection and detection data sharing.

All these show that biosensor-based instruments have big potential for development. However, few biosensor instruments are commercially available at the present time and are yet to be established as research or routine tools, due to these biosensor instruments still face many challenges hindering their real applications. ⑴The detection principle of the biosensor-based instruments are based on the specific recognition of biological elements, biological elements are easy to lose activity in real detection environment. ⑵The detection results are obtained with the help of electrochemical analytical instrument and the biosensor-based instruments lack a matched and complete analysis system. ⑶Most of the biosensor-based instruments are still at laboratory research stage and need to improve the accuracy and stability of the actual detection. The application of the biosensor-based instrument to the pesticides detection in various agricultural products such as vegetables and fruits will be further researched in the future.

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