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Role of Biosensors in Real Time Applications

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ABSTRACT: The human health safety is the real concern now days that are challenging science and technology as number of pollutants from various sources are affecting the life expectancy of human beings at each and every step. Numerous limitations associated with conventional chromatographic methods of detection such as heavy instrumentation along with complex and tedious steps involved during sample analysis, forced the researchers towards the development of most reliable and cost effective tools that not only monitor, analyze but also detect them in real time. Biosensors provide an optimal solution by integrating bioreceptors with physiochemical elements called as transducers to generate an electric current in human readout form, as a measure of target analyte concentration. Due to popularity of biosensor technology in recent years, their applications are prevalent in each and every field, from health monitoring, disease progression, contamination detection up to smart decision making capability to provide quick and precise outcomes. Biosensors have the potential to reveal the early onset of inflammation thus will provide the opportunity to fix disease and even prevent it before it occurs. This paper describes the tremendous potentiality of biosensors in human health care and environmental monitoring applications that are driven the market trends in evolution of biosensor technologies and innovating more up to date instruments in time. Intertwining nanotechnology in various biosensor applications results in exceptional improvement in performance parameters such as sensitivity, selectivity and portability. Finally, for future research and development in Biosensor field, our insights and challenges are also discussed in this paper.

Keywords: Acetylcholinesterase, Biosensor, Biomarkers, Glucose, Organophosphates, Pesticides.

Abbrebiations: hCG, Human chorionic gonadotropin; ACHE, Acetylcholinesterase; BCHE, Butrylcholinesterase; CVAAS, Cold vapour atomic absorption spectrometry; ICP-MS, Inductively coupled plasma mass spectrometry.

I. INTRODUCTION

In our everyday life we normally use several sensors in different electronic appliances. Biosensors are one of them that have turned out to be exceptionally prominent in recent years. Biosensor exhibits a synergic combo of biotechnology and microelectronics that provides electrical signal in human interpreted form, after being processed in various data conditioning circuits through interaction with biological or physiological systems [1]. But in real sense, converting biological information into an electronic signal requires a multidisciplinary learning in field of electronics, physics, biology as well as chemistry which is a huge assignment [2]. The popularity of utilization of biosensors in various commercial applications are because of their distinctive capacity to recognize wide range of multiple analytes at once, ecofriendly nature, simplicity in operation, high sensitivity, fast and convenient real time testing [3]. Traditional techniques available require highly qualified expertise to perform the laboratory testing, time consuming steps for sample preparation and no field detection possible. When compared with conventional laboratory based methods, Biosensors supports point of care testing that requires proper selection of biorecognition elements, immobilization strategies, electronic transducers and portable detector circuits against specific target analytes recognition. Popular areas implementing the utilization of biosensors includes food analysis and safety, glucose monitoring, early cancer diagnosis through recognition of cancer biomarkers, disease progression, drug discovery ans detection, biosample analysis (Blood, urine and saliva), Biodefence and lethal chemicals recognition as shown in Fig. 1 [4].

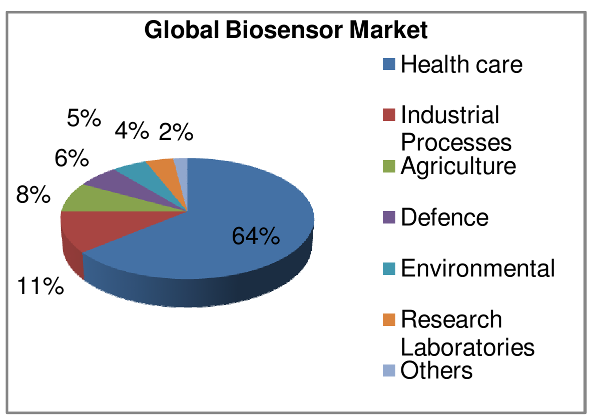

Fig. 1. Tentative market share of Biosensor applications.

The real success behind the rapid development of Biosensor technology lies in chemistry of interactions between biological and physicochemical components for the purpose of generating current or voltage as shown in Fig. 2.

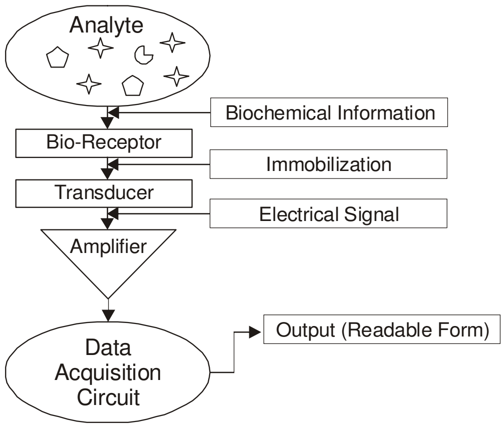

Fig. 2. Flow of Information in Biosensor.

Thus Biosensors undoubtedly play a dynamic role in achieving higher sensitivities of detection which is as low as pico and femto levels for recognition of target analytes, but the parameters for example stability, repeatability and reproducibility, still require an improvement for making its utilization widespread in variety of commercial applications.

II. BIOSENORS CLASSIFICATION

A. Non-invasive Biosensors

These are the novel devices that utilize the electromagnetic radiations for identification of any analyte. Rapidly increasing innovative work exercises for developing non-invasive biosensors is expected to drive growth of market soon [5]. Skin like biosensor as glucose monitoring device, that offers needle free estimation of glucose level in human blood is the best example for this type.

B. Wearable biosensors

These biosensors are gaining more intrigue and fascination because of their capability to provide continuous and real time data to measure the correlations between various concentrations in the human blood with the help of essential biomarkers such as saliva, sweat and tears [6]. These biosensors are digital devices that can be worn on the body such as shirts, glasses, watches, pair of shoes etc permitting their use in various real time applications such as medical, environmental, military, pharmaceutical and so on [7].

C. In Vivo and In vitro biosensors

These biosensors are arising as dominant tool in biomedical research for continuous checking of target analytes in biological samples [8]. In vitro and in vivo refers to experimental operations performed inside and outside a living structure.

III. BIOSENSOR MEDICAL APPLICATIONS

The market for biosensor development is gaining popularity at an amazing rate. The important medical applications that involve the utilization of biosensors include blood sugar level monitoring, early cancer detection, disease progression and pregnancy testing [9].

A. Glucose Monitoring

These biosensors have great potentiality to elevate the life expectancy of human beings at cost effective rates through biomonitoring of blood glucose levels at regular intervals. To balance the glucose levels in blood and optimum transformation of glucose into energy can be taken by cells throughout our body; pancreas produces Insulin, essential hormone in regulatory process of blood sugar levels. Diabetes, "An enemy of mankind" is an endocrine disrupter that impacts how our body used glucose: A vital element, which supplies energy to cells for growth and development of tissues and muscles. At present, two kinds of diabetes's are available: Type I and Type II.

A large portion of human community experienced this disease falls into Type-II category where human body became incapable to use the insulin secreted by pancreas [10]. While in Type-I, our body became helpless to produce the required insulin in the body [11]. Because of their severe impacts on human health, it's very essential to control the instant rise or fall of glucose levels in the body so that their aftermath impacts can be controlled to some extent. Biosensors came up with the solution, where an individual having not much trained knowledge to use the device, can operate and monitor the glucose levels in their body at multiple instants in a day.

Most commonly utilized methods for glucose monitoring involve electrochemical amperometric technique, due to inherent characteristics such as cost effective nature, portability, ease of electrode design and calibration compatibility [12]. Being diabetes a serious concern worldwide, glucose monitoring devices has been developed as a powerful tool in their effective regulation [13]. The technological advancements in the utilization of nanomaterials and mediators for the purpose of facilitating electron transfer across the electrodes were the key leaps which took glucose biosensors forward and empowered them to contend in the market with available ones for home blood glucose testing [14].

Majority of available blood glucose meters depend on dispensable electrode test strips, produced by the thick film microfabrication technology.

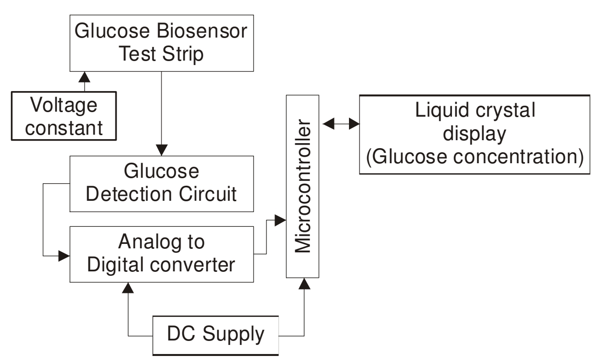

Fig. 3. Block diagram of Blood glucose monitoring device.

Each test strip contains working and reference electrodes, with the active portion of working electrode mostly coated with reagents such as enzyme, mediators, nano materials, immobilized on the electrode surfaces by an ink-jet printing technology. Block diagram for blood glucose monitoring is shown in Fig. 3.

This biosensor approach offers considerable promise for extracting the useful electronic information from the biological one in cheaper, faster and user friendly manner when compared with laboratory traditional assays available [15]. Noninvasive approaches for continuous glucose monitoring provide an encouraging track to anticipate the challenges in the present trends.

Working Principle: When the enzyme molecules such as glucose oxidase present on working electrode surface of transducer perceives the glucose molecules present in blood, it produces hydrogen peroxide and gluconic acid in the presence of oxygen from air as shown below. There is an electron transfer at the electrode surface due to reduction of hydrogen peroxide/oxygen coupling. Flow of electrons is corresponding to glucose concentration in blood [16]. To enhance flow of the electrons, mediators such as Ferrocyne and Ferricyanide can be used on electrodes surfaces. Current of microamperes so generated due to reduction of an electroactive species is then processed with signal conditioning circuits to get the information in human readable form.

$$\text{Glucose} + O_2 + H_2O \xrightarrow{\text{GoD}} + \text{Gluconic acid} + H_2O_2 \quad (1)$$

$$H_2O_2 + 2e^- \xrightarrow{\text{Reduction}} O_2 + 2H^+ \quad (2)$$

B. Cancer Detection

Cancer is a lethal disease, brought about by abnormal and unchecked cell growth due to accumulation of hereditary transformations that had ruined numerous lives throughout the years. Cancer if recognize at the starting stage, can be cured through proper treatment, thereby will increase the survival rate of patient. In this way, early diagnosis of cancer is very significant to enhance the chance that treatment will be effective [17]. The present strategy available for cancer treatment is biopsy method, which is an intrusive medical procedure. Inferable from the few constraints of the available techniques worldwide, had compelled the researchers towards the development of smart devices that can allow the non invasive identification of cancer cells and their biomarkers [18]. Biosensors provide a versatile platform for rapid and sensitive detection of cancer biomarkers, which will definitely help in reducing the demise rates of human beings in the future [19]. Biomarker is a biological molecule present in body fluids such as blood, urine or serum, whose activity measurement, either behavioral or structural represents normal or abnormal functioning of various body organs.

Table 1: Cancer and their biomarkers.

Type of cancer	Biomarkers	References
Breast Cancer	Human epidermal growth factor receptor 2 (HER2/neu), Carcino-embryonic antigen (CEA), carbohydrate antigens (CA 15-3), Estrogen receptor (ER) and progesterone receptor (PgR) etc.	[23, 24]
Liver Cancer	Alpha-Fetoprotein (AFP), Glypican-3 (GPC3)	[25]
Prostate Cancer	Prostate Specific Antigen (PSA), spondin-2 (SPON2) micro RNA in urine etc.	[26, 27]
Ovarian Cancer	Cancer antigen 125 (CA125), Human Epididymis protein 4 (HE4) and Risk of Malignancy Index (RMI).	[28]
Lung Cancer	SCC (Squamous Cell Carcinoma Antigen), NSE (Neuron-Specific-Enolase), Cancer antigen 125 (CA125), PKLK (Plasma Kallikerian), EGFR (Epidermal Growth factor)	[29]
Gastric Cancer	Micro RNA (miRNA), DNA hypomethylation, Carcino-embryonic antigen (CEA), PARP1.	[30, 31]

These biosensors interact with biomarkers with the help of biorecognition elements immobilized on transducer surfaces, work against specific target analytes to produce an electric current proportional to changed activity of biomarker [20].

Working Principle: Biosensor construction generally involve enzyme, antibody or microbial immobilization, protein protein interactions, surface modification followed by electrochemical, optical or piezoelectric detection to measure a conformation changes in the bioreceptors upon interaction with target biomarkers and analytes to yield an electrical signal in the form of current, voltage, resistance, mass change or variation in optical properties [22]. Amperometric and Potentiometers biosensors are the two most common electrochemical biosensors used for detection of cancer biomarkers. Constant potential between enzyme electrodes and oxidation-reduction reactions on the active transducer surfaces are responsible for generating current in case of amperometric biosensors, while potentiometric biosensors rely on the use of ion selective electrodes to generate electric response, whenever a target analyte interacts with bioreceptors.

Electrochemical biosensors supports direct measurement of cancer biomarkers for low level specific analytes present in blood, serum, saliva and urine. Moreover, the amalgamation of electrochemical technology with nano featured tubes, particles and crystals such as carbon nanotubes, cadmium telluride nanoparticles and grapheme quantum dots nanocrystals provide multiplexing capability and rapid electron transfer at the active transducer surface, thereby enhances the sensitive and concurrent recognition of biomarkers of cancer [21].

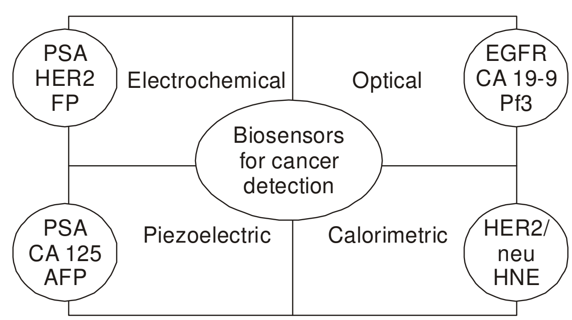

Fig. 4. Cancer Biosensors and their biomarkers.

Some of the cancer biosensors and their biomarkers are shown in Fig. 4.

C. Pregnancy Testing

Proteins play important roles in regulating various biological processes. Thus their presence or absence within our body could be useful biomarkers of our health perception. The biomarkers behavior towards specific analytes can be useful to know whether somebody has a specific disease or not, thereby suitable treatment can be given to the person with respect to reactions received. Early diagnosis and monitoring disease progression is an essential prerequisite for preventing the proliferation of infection in the body and in this way can enhance the life expectancy of human beings.

Human chorionic gonadotropin (hCG), glycoprotein hormone is an important biomarker for pregnancy testing [32-34]. Conventionally, chemical tests involve lateral flow technology and combination of antibodies (mhCG) to selectively detect the elevated levels of beta subunit of hCG in urine. Data analysis and interpretation are to be performed by user. Test sensitivity, ease of use, response time, user friendly nature and price are the essential factors responsible for viability of their utilization. One such example is development of novel chemically modified graphene channels coupled with bioreceptors as antibodies for ultrasensitive detection of hCG biomarker in human body [35]. Now days, color-changing strips are used to recognize pregnancy hormones in urine.

IV. BIOSENSOR ENVIRONMENTAL APPLICATIONS

The constantly increasing number of lethal pollutants in the environment requires instant attention towards the development of rapid and cost effective techniques that can monitor as well as detect the pollutants in real time [36]. Biosensor technology came up with an alternate option, for rapid target analyte detection through combination of biological and physio-chemical mechanisms over conventionally available chromatographic techniques. The main advantages offered by biosensors in various environmental monitoring applications are portability, ease of use, miniaturization, in-situ measurement of complex pollutants through minimal sample preparation, utilization and extraction methods [37-38]. Components of an environmental monitoring is shown in the Fig. 5.

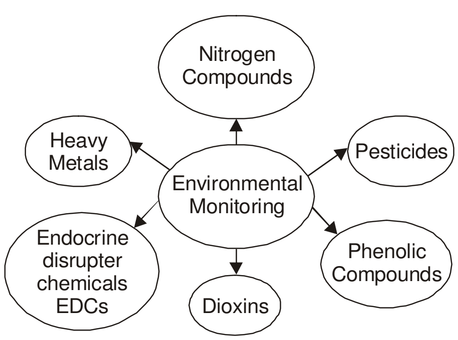

Fig. 5. Environmental Monitoring.

A. Heavy Metals Recognition

The use of heavy metals in the environment is the major cause to environmental pollution and serious human health issues (i.e. Disturbance to reproductive, kidney and liver functions) because of their highly toxic nature. These metals are non biodegradable commonly, hence can stay in environment significantly after longer periods of exposure. Metals that have thickness more than 5 g/cm^3 are known as heavy metals. Some are essential at lower concentrations like iron, zinc, copper and nickel. The most common heavy metal contaminants with highly lethal nature found in the environment are lead (Pb), mercury (Hg) and Cadmium (Cd).

Conventional techniques such as CVAAS [39], ICP-MS [40], polarography etc. available for heavy metals recognition are very precise and accurate, however suffer from the detriments of significant expense, requirement of trained work force and laboratory restricted. Biosensors offer a considerable promise in analysis of harmful metal pollutants through Proteins (enzyme, antibody, metal-binding) and whole-cell microbial (natural/genetically modified) based techniques. Incorporation of nanotechnology in biosensors leads to significant improvement in their characteristic parameters [41-42].

Heavy metal ion contaminations are widely determined by enzymatic methods based on enzyme's inhibition or activation [43]. Biosensors which monitor enzyme inhibition or activation provide fast response times, however lacking in specificity and involving time consuming enzyme electrodes preparation and extraction steps, diverted our attention towards development of more specific target analyte bioreceptors. Antibodies and whole cells (Genetically Engineered microorganisms) as bioreceptors came up with an alternative to produce a quantifiable signal [44, 45].

B. Pesticide recognition

The exponentially increasing population with constrained sources put a colossal weight on the farming segment to increase sufficient productivity, so that basic necessities of every citizen can be met. This intense pressure has increased the utilization of pesticides up to many folds, resulting in an environmental pollution and concern of severe human health issues. Biosensors seem to be promising tool for recognizing the harmful chemicals in real time when compared with traditional methods [46-47].

These pesticides are highly toxic compounds; usually act by inhibiting several cholinesterase enzymes essential for signal transmission and reception in nerves and muscles. Organophosphorous and carbamate pesticides represent a large percentage of extensively used pesticides and have harmful health impacts on the individuals as they act as inhibitors of cholinesterases (ACHE and BCHE) leading to excess acetylcholine accumulation at nerve terminals due to formation of protein-pesticide adducts. The elevated acetylcholine levels in biological samples due to enzyme inhibition by these pesticides are the root cause of numerous syndromes such as severe impairment of nerve functions and even death of human being [48-49]. Thus great majority of enzyme sensors for pesticide detection deals with the monitoring of acetylcholinesterase activity change [50].

Working Principle: Electrochemical biosensors based on ACHE inhibition involves the measurement of the change of the activity of an acetylcholinesterase before and after composure to the pesticides, caused by oxidation or reduction of electroactive compound, produced due to enzymatically catalyzed hydrolysis of substrate acetylthiocholine [48]. Electrochemical biosensor with portable detection circuit is shown in Fig. 6.

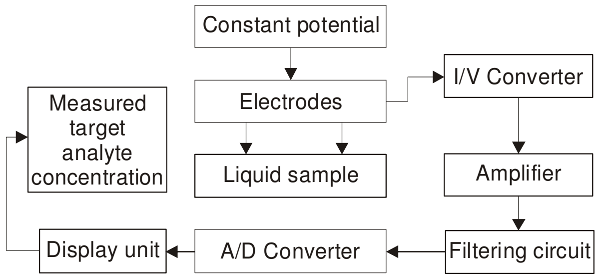

Fig. 6. Electrochemical Biosensor with portable detection unit for pesticide recognition.

V. CONCLUSION AND ISSUES

This paper precisely presents the potentiality of Biosensors in the field of health care, agriculture and environmental monitoring programs to give ultimate benefit to society. Due to Biosensor's incredible alluring prospects such as cost effectiveness, portability and ease of operation, it has been the center of attention for recent decades. These devices interact with the analytes of interest to transform the biological information into an electric signal. Applications of nanomaterials to improve mechanical, electrochemical, optical and magnetic properties of immobilized materials in biosensors provide opportunities to generate appreciable active current flow on transducer surfaces at lower potentials. The availability of advanced bioreceptors specific to target analyes, interdisciplinary knowledge, surface modification techniques, interfacing methods, characterization, high quality nanomaterials and the mechanisms governing their behaviour on electrodes surfaces are still presenting a great challenge for the widespread use of biosensors in commercial applications.

VI. FUTURE SCOPE

Most of the work so far in the biosensor field had focused on the healthcare applications according to the literature survey. There is still need to utilize the biosensor potential in defense, agriculture and environmental applications that can be achieved only after properly exploiting the inherent features of advanced bioreceptors in conjunction with microelectronics and nanotechnology.

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Conflict of Interest. None.

REFERENCES

[1]. Shruthi, G. S., Amitha, C. V., & Blessy, B. M. (2014). Biosensors: A Modern Day Achievement. *Journal of Instrumentation Technology, 2*(1), 26-39.

[2]. Gonzalez-Rodriguez, J., & Raveendran, M. (2015). Importance of Biosensors. *Biosensors Journal, 4*(1). DOI:10.4172/2090-4967.1000e104.

[3]. Darsanaki, R. K., Azizzadeh, A., Nourbakhsh, M., Raeisi, G., & Alibadi, M. A. (2013). Biosensors Functions and Applications. *Journal of Biology and Today's World*, *2*(1), 53-61.

[4]. Vigeshvar, S., Sudhakumari, C. C., Senthilkumaran, B., & Prakash, H. (2016). Recent Advances in Biosensor technology for Potential applications - An overview. *Frontiers in Bioengineering and Biotechnology, 4*(11), 1-9.

[5]. Wang, J. (2001). Glucose Biosensors: 40 years of Advances and Challenges. *Electroanalysis, 13*(12), 983-988.

[6]. Kim, J., Campbell, A. S., Esteban-Fernandez de Avila, B., & Wang, J. (2019). Wearable biosensors for healthcare monitoring, *Nature Biotechnology*, *37*, 389-406.

[7]. Ajami, S., & Teimouri, F. (2015). Features and application of wearable biosensors in medical care. *Journal of Research in Medical Sciences, 20*(12), 1208-1215.

[8]. Rong, G., Corrie, S.R., & Clark, H.A. (2017). In vivo biosensing: progress and perspectives. *ACS Sensors*, *2*(3), 327-338.

[9]. Mukhtar, T. (2016). Healthcare Biosensors – A paradigm shift to wireless technology. *International Journal of Advanced Research in Computer and Communication Engineering*, *5*(8), 32-41.

[10]. Zimmet, P. Z. (2017). Diabetes and its drivers: the largest epidemic in human history? *Clinical Diabetes and Endocrinology, 3*(1), 1-8.

[11]. Todkar, S. S. (2016). Diabetes Mellitus the 'Silent Killer' of mankind: An Overview on the eve of Upcoming World Health Day!. *Journal of Medical & Allied Sciences*, *6*(1), 39-44.

[12]. Wang, J. (2000). Electrochemical glucose biosensors. *Chemical Reviews*, *108*(2), 814-825.

[13]. Yoo, E-H., & Lee, S-Y. (2010). Glucose Biosensors: An Overview of use in clinical practice. *Sensors*, *10*, 4558-4576.

[14]. Scognamiglio, V., & Arduini, F. (2019). The technology tree in the design of glucose biosensors. *Trends in Analytical Chemistry, 120,* 1-15.

[15]. Mule, S. S., Mujawar, T. H., Bachuwar, V. D., Kasbe, M. S., & Deshmukh, L. P. (2016). Design and Development of Digital Blood Glucose Meter based on Microcontroller 8051. *International Journal of Innovation in Engineering, Research and Technology,* 1-6.

[16]. Latha, N. A., Murthy, B. R., & Sunitha, U. (2012). Design and Development of a Microcontroller based system for the Measurement of Blood Glucose. *International Journal of Engineering Research and Applications, 2*(5), 1440-1444.

[17]. Griffin, S. (2017). Biosensors for cancer detection applications. *Missouri S&T's Peer to Peer*, *1*(2), 1-12.

[18]. Devi, N., & Laskar, S. (2018). A review on Applications of Biosensors for cancer detection. *ADBU Journal of Electrical and Electronics Engineering, 2*(2), 17-21.

[19]. Bohunicky, B., & Mousa, S.A. (2010). Biosensors: the new wave in cancer diagnosis. *Nanotechnology Science and Applications, 4,* 1-10.

[20]. Patel, P., & Patel, J. (2017). Biosensors and Biomarkers: promising tools for cancer diagnosis. *International Journal of Biosensors & Bioelectronics*, *3*(4), 313-316.

[21]. Topkaya, S.N., Azimzadeh, M., & Ozsoz, M. (2016). Electrochemical Biosensors for Cancer Biomarkers Detection: Recent Advances and Challenges. *Electroanalysis, 28*, 1-19.

[22]. Jayanthi, V. S. P. K. Sankara A., Das, A. B., & Saxsena, U. (2017). Recent advances in biosensor development for the detection of cancer biomarkers. *Biosensors & Bioelectronics*, *91*(15), 15-23.
[23]. Sarvari, G., Sandya Rani B., & Bitla, A. R. (2017). Breast cancer diagnosis – role of biomarkers. *Journal of Clinical & Scientific Research, 6*, 225-236.
[24]. Nunez, C. (2019). Blood based protein biomarkers in breast cancer. *Clinica Chimica Acta*, *490*, 113-127.
[25]. Wang, S., Wang, J., Zhu, Y., Yang, J., & Yang, F. (2015). A new device for liver cancer biomarker detection with high accuracy. *Sensing and Bio-Sensing Research, 4*, 40-45.
[26]. Singh, S., Gill, Atal A. S., Nlooto, M., & Karpoormath, R. (2019). Prostate cancer biomarkers detection using nanoparticles based electrochemical biosensors. *Biosensors & Bioelectronics, 137*, 213-221.
[27]. Parra-Cabrera, C., Samitier, J., & Homs-Corbera, A. (2016). Multiple biomarkers biosensor with just-in-time functionalization: Application to prostate cancer detection. *Biosensors & Bioelectronics, 77*, 1192-1200.
[28]. Ueland, F. R. (2017). A perspective on ovarian cancer biomarkers: past, present and yet-to-come. *Diagnostics*, *7*(1), 14.
[29]. Roointan, A. Mir, T.A., Wani, S.I., Rehman, M. U., Hussain, K.K., Ahmed, B., Abrahim, S., Savardashtaki, A., Gandomani, G., Gandomani, M., Chinnappan, R., Akhtar, M. H. (2019). Early detection of lung cancer biomarkers trough biosensor technology –a review. *Journal of Pharmaceutical & Biomedical Analysis, 164*, 93-103.
[30]. Jianga, F., Hong, F., Shah, Md.W., & Shen, X. (2019). Circular RNAs as diagnostic biomarkers in gastric cancer: A meta-analysis review, *Pathology Research & Practice, 215*(6), 1-8.
[31]. Afzal, H., Yousaf, S., Rahman, F., Ahmed, M. W., Akram, Z., Kayani, M. A., & Mahjabeen, I. (2019). PARP1:A potential biomarker for gastric cancer. *Pathology-Research and Practice*, *215*(8). DOI:10.1016/j.prp.2019.152472.
[32]. Rausch, M. E., & Barnhart, K. (2012). Serum biomarkers for detecting ectopic pregnancy. *Clinical Obstetrics and Gynecology, 55*(2), 418-423.
[33]. Rizwan Md., Hazmi, Md., Abdullah Lim, S., & Ahmed, M. U. (2019). A highly sensitive electrochemical detection of human chorionic gonadotropin on a carbon nano-onions/goldnanoparticles/polyethylene glycol nanocomposite modified glassy carbon electrode. *Journal of Electroanalytical. Chemistry, 833,* 462-470.
[34]. Stenman, U.H., Emertius, & Alfthan, H. (2013). Determination of human chorionic gonadotropin. *Best practice & Research Clinical Endocrinology & Metabolism*, 27(6), 783-793.
[35]. Teixeiral, S., Conlan, R. S., Guy, O. J., Goreti Ferreira Sales, M. (2014). Label-free human chorionic gonadotropin detection at picogram levels using oriented antibodies bound to graphene SPEs. *Journals of Material chemistry, 2*(13), 1852-1865.
[36]. Medeiros Salgado, A., Sliva, L.M. & Farias Melo, A. (2011). Biosensors for Environmental Applications. In: *Somerset, V. Environmental Biosensors* (pp. 1-16), *Intech, Croatia*.
[37]. Shukla, P., Nigam, V., Gupta, R., Singh, A., & Kuhad, R. C. (2013). Sustainable enzyme technology for environment: biosensors for monitoring of pollutants and toxic compounds. In *Biotechnology for Environmental Management and Resource Recovery* (pp. 69-76). Springer, India.
[38]. Badihi-Mossberg, M., Buchner, V., & Rishpon, J. (2007). Electrochemical biosensors for pollutants in the environment. *Electroanalysis, 19*(19-20), 2015-2028.
[39]. Wang, Z., Wang, X., Wang, Q., Xiong, X., Luo, H., & Huang, K. (2019). Recent developments in chemical vapor generation atomic spectrometry for zinc detection. *Microchemical Journal*, *149*,1-8. DOI: 10.1016/j.microc.2019.104052.
[40]. Bakkali, K., Martos, N.R., Souhail, B., & Ballesteros, E. (2012). Determination of Heavy Metal Content in Vegetables and Oils from Spain and Morocco by Inductively Coupled Plasma Mass Spectrometry. *Analytical Letters*, *45*(8), 907-919.
[41]. Verma, N., & Singh, M. (2005). Biosensors for heavy metals. *BioMetals*, *18*(2), 121-129.
[42]. Turdean, G. L. (2011). Design and development of Biosensors for the detection of heavy metal toxicity. *International Journal of Electrochemistry,* 1-15.
[43]. Upadhyay, Lata S.B., & Verma, N. (2013). Enzyme inhibition based biosensors- A Review, *Analytical Letters, 46,* 225–241.
[44]. Blake, D. A., Jones, R.M., Blake II, R. C., Pavlov, A. R., Darwish, I. A. & Yu, H. (2001). Antibody-based sensors for heavy metal ions, Biosensors & Bioelectronics, *16*(9-12), 799-809.
[45]. Bereza-Malcolm, L. T., Mann, G., & Franks, A. E. (2015). Environmental Sensing of Heavy Metals Through Whole Cell Microbial Biosensors: A Synthetic *Biology Approach. ACS Synthetic Biology, 4*(5), 535-546.
[46]. Marty, J. L., Leca, B., & Noguer, T. (1998). Biosensors for the detection of pesticides. *Analusis*, *26*(6), 144-148.
[47]. Wang, Q., Xiong, Y., & Lou, L. (2015). Biosensors for detection of pesticide residues. *American Journal of Nano Research and Application, 3*(1), 18-22.
[48]. Jones, K., Everard, M., & Harding, A. H. (2014). Investigation of gastrointestinal effects of organophosphate and carbamate pesticide residues on young children. *International Journal of Hygiene and Environmental Health,* 217, 392-398.
[49]. Georgiadis, G., Mavridis, C., Belantis, C., Zisis, I. E., Skamagkas, I., Fragkiadoulaki, I., Heretis, I., Tzortzis, V., Psathakis, K., Tsatsakis, A., & Mamoulakisa, C. (2018). Nephrotoxicity issues of organophosphates, *Toxicology*, 406-*407*, 129-136.
[50]. Dhull, V., Gahlat, A., Dibaghi, N. & Hooda, V. 2013. Acetylcholinesterase Biosensors for Electrochemical Detection of Organophosphorus Compounds: A Review. *Biochemistry Research International*, 1-18.
[51]. Sun, X., & Wang, X. (2010). Organophosphorous Pesticides detection system based on Amperometric Enzyme Biosensor. In *Proceedings of International conference on Information Science and Engineering*, *IEEE*, 391-394.

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