UNIVERSITI PUTRA MALAYSIA

FABRICATION OF CALIXARENE-BASED GRAPHENE-MODIFIED SCREEN-PRINTED CARBON ELECTRODES FOR SELECTIVE DETECTION OF ANTHRACENE

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By

PUTRI NUR SYAFIEQAH BINTI ZAINAL

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Chair : Associate Professor Shahrul Ainliah Alang Ahmad, PhD
Faculty : Science

Anthracene is one of the most widespread polycyclic aromatic hydrocarbons (PAHs) that consists of three fused benzene rings. To date, numerous approaches have been reported for electrochemical detection of anthracene based on various materials. Nevertheless, the critical issues in designing electrochemical sensors are the strategy to enhance the selectivity, sensitivity, and stability of the detection in environmental samples. Therefore, in this research work, different calix[4]arene-based materials such as tert-butyl-calix[4]arene (C4), thiolated-calix[4]arene (TC4) and, calix[4]arene-based metal-organic framework (C4TCA@MOF) were used as a receptor and incorporated with coupling materials, which are electrochemically reduced graphene oxide (ERGO) and gold nanoparticles (AuNPs) to develop different strategies of electrochemical sensor for the determination of anthracene. In brief, the first sensor was constructed based on C4 deposited on ERGO/SPCE (C4/ERGO-SPCE). The next sensor was proposed with a coupling material, AuNPs that was prepared through the synthetic route of Turkevich-Frens method and functionalized with TC4 to form TC4/AuNPs/ERGO-SPCE. Next, the third sensor was constructed by synthesizing a C4TCA@MOF through solvothermal method as a new receptor and deposited on AuNPs/ERGO (C4TCA@MOF/AuNPs/ERGO-SPCE). Under the optimal conditions, the C4/ERGO-SPCE exhibited a good linearity towards anthracene with concentration range from 2-8 μM and limit of detection (LOD) 0.02637 μM, while the performance of TC4/AuNPs/ERGO-SPCE increase comprehensively due to the presence of AuNPs with a linear concentration range from 1-7 μM and LOD 0.00649 μM. After the modification of C4 into C4TCA@MOF, the proposed sensor (C4TCA@MOF/AuNPs/ERGO-SPCE) revealed highest sensitivity and selectivity and demonstrated wide linear concentration range from 0.01-30 μM with LOD 0.00521 μM. The proposed sensor also was tested towards anthracene using portable potentiostat that was able to demonstrate a

satisfactory recoveries (90-93%) and statistical analysis of relative error (2.27-4.60%). With these proven advantages, the proposed sensors have a huge potential as an alternative analysis of anthracene in near future.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

FABRIKASI ELEKTROD BERASASKAN KALIKS[4]ARINA DAN GRAFIN KE ATAS ELEKTROD SKRIN BERCETAK KARBON UNTUK PENGESANAN SELEKTIF ANTRASIN

Oleh

PUTRI NUR SYAFIEQAH ZAINAL

March 2021

Pengerusi : Professor Madya Shahrul Ainliah Alang Ahmad, PhD
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Antrasin adalah salah satu polisiklik aromatik hidrokarbon (PAHs) yang ditemui secara meluas, terdiri daripada 3 gelang benzena terlakur. Sehingga kini, banyak pendekatan telah dilaporkan untuk pengesanan elektrokimia antrasin berdasarkan pelbagai bahan. Walau bagaimanapun, masalah kritikal dalam merangka sensor elektrokimia adalah strategi untuk meningkatkan selektiviti, kepekatan dan kestabilan pengesanan dalam sampel persekitaran. Justeru, dalam kerja penyelidikan ini, bahan berasaskan kaliks[4]arina yang berbeza seperti tert-butil-kaliks[4]arina (C4), kaliks[4]rina tiolat (TC4) dan struktur logam organik berasaskan kaliks[4]arina (C4TCA@MOF) digunakan sebagai reseptor dan digabungkan dengan bahan gandingan yang merupakan grafin oksida elektrokimia terturun (ERGO) dan nanopartikel emas (AuNPs) untuk membangunkan strategi sensor elektrokimia yang berbeza untuk penentuan antrasin. Secara ringkasnya, sensor pertama dibina berdasarkan pemendapan C4 ke atas ERGO/SPCE. Sensor seterusnya diusulkan dengan bahan gandingan, AuNPs yang disediakan melalui laluan sintetik *Turkevich-Frens* dan difungsikan dengan TC4 untuk membentuk TC4/AuNPs/ERGO-SPCE. Seterusnya, sensor ketiga dibina dengan mensintesis C4TCA@MOF melalui kaedah solvotermal sebagai reseptor dan dimendapkan ke atas AuNPs/ERGO (C4TCA@MOF/AuNPs/ERGO-SPCE). Di bawah keadaan optimum, C4/ERGO menunjukkan kelinearan yang baik terhadap antrasin dalam julat kepekatan dari 2-8 µM dengan had pengesanan (LOD) 0.02637 µM, sementara itu prestasi TC4/AuNPs/ERGO-SPCE meningkat secara komprehensif disebabkan oleh kehadiran AuNPs dengan kepekatan linear dari 1-7 µM dan LOD 0.00649 µM. Selepas pengubahsuaian C4 menjadi C4TCA@MOF, sensor yang dicadangkan C4TCA@MOF/AuNPs/ERGO-SPCE telah menunjukkan menunjukkan kepekatan dan selektiviti yang tertinggi dan menunjukkan julat kepekatan linear yang ketara dari 0.01-30 µM dengan LOD 0.00521 µM. Sensor yang dicadangkan juga diuji dengan menggunakan potentiostat mudah alih terhadap antrasin yang dapat menunjukkan perolehan semula yang memuaskan

sebanyak 90-93 % dan analisis statistik ralat relatif 2.27-4.60 %. Dengan terbuktinya kelebihan ini, sensor yang dicadangkan mempunyai potensi yang besar sebagai analisis alternatif antrasin dalam masa terdekat.

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I dedicate this thesis to all of them.

DR. PUTRI NUR SYAFIEQAH ZAINAL

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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LIST OF ABBREVIATIONS

AuNPs	Gold Nanoparticles
CV	Cyclic Voltammetry
C4	4-tertbutylcalix[4]arene
TC4	Thiolated Calix[4]arene
C4TCA	Calix[4]arene Tetracarboxylic Acid
DPV	Differential Pulse Voltammetry
ERGO	Electrochemically Reduced Graphene Oxide
MOF	Metal-Organic Framework
FESEM	Field Emission Scanning Electron Microscopy
FT-IR	Fourier Transform Infrared Spectroscopy
GO	Graphene Oxide
HPLC	High Performance Liquid Chromatography
HRTEM	High-Resolution Transmission Electron Microscopy
LOD	Limit of Detection
PAHs	Polycyclic Aromatic Hydrocarbons
SPCE	Screen Printed Carbon Electrode
TC4	Thiolated-Calix[4]arene
USEPA	United States Environmental Protection Agency
UV-VIS	Ultraviolet Visible
PXRD	Powder X-Ray Diffraction
EIS	Electrochemical Impedance Spectroscopy
USEPA	United States of Environment Protection Agency
SPR	Surface Plasmon Resonance
S/N	Signal/Noise

LLE	Liquid-liquid Extraction
Rct	Charge transfer resistance
Cdl	Double-layer capacitance

CHAPTER 1

INTRODUCTION

1.1 Background of research

Polycyclic aromatic hydrocarbons (PAHs) are comprised of two or more aromatic rings fused together in a linear, angular or cluster arrangement (Broniatowski *et al.*, 2017; Arey & Atkinson, 2003). They are considered as carcinogenic, mutagenic and teratogenic compounds which can cause to long-term health effects such as cancer (Armstrong *et al.*, 2004), suppress the immune function (Burchiel & Luster, 2001) and induce genotoxic damage (Gamboa *et al.*, 2008; Brookes & Lawley, 1964). Naturogenic sources such as forest fire, organic matter diagenesis, and volcanic activity can cause PAHs to be released into environmental matrices. However, in the majority cases, the origination of PAHs is corresponded to the chemicals associated with petroleum-related activities. PAHs have polluted both marine and freshwater reservoir over the years via oil and gas operations, including the discharge of petroleum-incorporated substances (Yu *et al.*, 2019; Sun *et al.*, 2018). The worst-case scenario, due to their physicochemical properties, PAHs are deemed to be highly mobile in the environment which facilitate them to experience long-range dispersion, triggering global pollution issues (Dat & Chang, 2017). Due to the harmful properties, 16 major PAHs have been classified as the most impacted pollutants that are governed by the United States Environmental Protection Agency (USEPA) and the European Union (EU) (Andersson & Achten, 2015).

Out of 16 PAHs reported, 2- to 3-ring PAHs such as naphthalene and anthracene are comparatively more crucial and environmentally harmful due to their higher emission percentage and greater water solubility (Andersson *et al.*, 2005). In fact, they are prevalent micropollutants in the atmosphere and environmental water. As a result, anthracene with 3-fused benzene rings serve as representative role in the environmental matrices and need to be regularly monitored for controlling purposes due to its properties that are persistent, bioaccumulative and toxic to human health and environment (Zhang *et al.*, 2011; Zhuang & Zhou, 2009). Thus far, numerous traditional approaches have been examined using chromatographic techniques such as HPLC (Toriba *et al.*, 2003), GC (Zhang *et al.*, 2010; Paputa-Peck *et al.*, 1983), and LC-MS (Wolkenstein, 2019; Itoh *et al.*, 2006) to classify anthracene and its family members of PAHs. Despite of their high sensitivity and selectivity, these methods suffer from intricate sample pre-treatment steps and involve the employment of expensive and huge instruments that are impractical for routine control assessment. In recent years, the miniaturization of the chromatographic system has received remarkable attention which involves a small sample and reagents volume (Yuan

& Oleschuk, 2018). Nonetheless, a major consideration associated with the portable chromatographic devices is the difficulty in stationary phase coating where the µ-column used in the system is relatively too short for adequate separation of complex samples such as PAHs. Furthermore, the introduction of small-scale working pressure to the cylinder pressure of the gas used can reduced the sensitivity significantly due to the constant interruption of the analysis to refill the mobile phase reservoir, thus affect the flow rates of the mobile phase. In addition, the miniaturization process also reduced the injection volumes, hence reduced the sensitivity due to the limited number of compounds with fluorescence and absorbance properties (Nazario *et al.*, 2015). These challenges have evolved the research's interest in developing advanced analysis technologies with the simplest integrated system without compromising the sensitivity. Recently, the electrochemical method has taken centre stage as an alternative way to conventional chromatographic techniques for the determination of PAHs due to their properties that are easy to prepare and construct, inexpensive, sensitive, environmental friendly and applicable for on-site detection (Zhu *et al.*, 2014). Electrochemical sensors represent the most remarkable device in analytical chemistry that enable to provide any information regarding the composition of a system in real-time by coupling an electrochemical transducer to a chemically selective layer (receptor-recognition element) through redox reaction. The selective interaction between the recognition element and chemical species (target analyte) is transformed into a detectable signal, where the signal generated is proportional to the concentration of the analyte. Therefore, the exploration of a simplified integrated system based on the electrochemical approach will bring a new evolution as a decentralized analysis with favourable features in the near future.

1.2 Problem statements and research motivation

As comparative analysis to mass, optical and thermal sensors, the electrochemical sensors have been receiving tremendous consideration over traditional techniques such as chromatography and spectroscopy in a vast range of important applications in the field of clinical, industrial, environmental, and agricultural analysis. Nevertheless, the critical issues in designing electrochemical sensors are the strategy to enhance the selectivity, sensitivity, and stability for the detection of the environmental samples. Therefore, it is necessary to explore further the performance and efficiency of the electrode by introducing a variety of receptors for chemically modified electrodes (CMEs) to address the challenges. Over the past decades, the field of CMEs have experienced a period of rapid growth to exert more direct control over the chemical nature of an electrode surface. The capability of CMEs to deliberately control and manipulate the surface properties actively can meet the needs of sensing problems, leading to a variety of desirable outcomes; improve selectivity and sensitivity, increase stability, offer wider potential window, and enhance fouling resistance. Thus far, numerous researches have been conducted on determination of anthracene in real water samples. Despite of their promising analysis at a very low concentration, the developed CMEs had the adsorption capacity to some PAHs interferent up to 20% due to the unspecific active material used for the electrode modification.

Recently, macrocycles, known as calix[n]arenes which belong to the cyclic oligomer subclass have been highlighted in numerous precedent studies as perceptible recognition elements for cations, anions, and neutral target molecules. The incorporations of a central cavity in the cone conformation are capable to form stable host-guest complexes by possessing supramolecular ability with various guests (Kang *et al.*, 2000; Kim *et al.*, 1999). Furthermore, the versatility of these macrocycles that able to vary in size, shape and functional groups have driven these macrocycles as highly selective receptor since they have different binding affinities towards various molecules depending on the purposes. However, despite their promising synergistic properties in a sensing application, the employment of calix[n]arenes as a chemiresistive sensor remain reasonably unexplored due to the poor conductivity. Therefore, in this work, different integration strategies were outlined by utilizing the coupling materials; electrochemically reduced graphene oxide (ERGO) and gold nanoparticles (AuNPs) to explore the performance of the developed sensors with regards to electrochemical properties, sensitivity and selectivity for the detection of anthracene.

1.3 Research objectives

The general objective of this thesis is to present the findings of the research strategy in designing the electrochemical sensors based on different calix[4]arene-based for the detection of anthracene. The thesis will provide analytical and physicochemical data of the developed sensors. The following specific objectives targeted for this research:

i. To modify, characterize and optimize different strategies in developing of calix[4]arene-based sensor [namely (C4/ERGO-SPCE, TC4/AuNPs/ERGO-SPCE and C4TCA@MOF/AuNPs/ ERGO-SPCE)].
ii. To examine the analytical performance of the developed calix[4]arene-based sensors for electrochemical analysis of anthracene.
iii. To integrate the developed sensor C4TCA@MOF/AuNPs/ERGO-SPCE with portable potentiostat.
iv. To evaluate the performance of the fabricated prototype towards real sample analysis.
v. To validate the developed sensor and portable potentiostat towards the established technique (HPLC).

1.4 Novelty of research

To the best of our knowledge, the proposed sensors was the first attempt reported for anthracene determination with an advanced features such as highly efficient material, cost-effective and eco-friendly. Significantly, by utilizing calix[4]arenes-based material as a receptor for chemically modified electrode, an excellent selectivity performance was achieved due to the behavior of calix[4]arene cavity size that matches more efficiently with the molecular size of anthracene. By outclassing the problems arose from the established techniques such as time consuming and tedious sample preparation, the sensor reported in this work has a potential as a promising tools for monitoring the level of anthracene in environmental matrices which then can be used to make decision or warning to protect public health and environment.

1.5 Scope of the study

This study focuses mainly on developing electrochemical sensors by employing different calix[4]arene-based receptors for the detection of anthracene. Generally, calix[4]arenes have poor conductivity and stability which limit its application in the electrochemical assay. Hence, the integration of calix[4]arenes with supporting materials was further explored for sensor characteristic improvement. The first electrochemical sensor developed was fabricated by employing ERGO as an immobilization matrix to increase the active surface area for the deposition of calix[4]arene (C4/ERGO). In spite of the significant increase in the availability of calix[4]arene cavities, the developed sensor, however, suffers from current instability due to the poor conductivity properties. The next developed sensor was designed to introduce a conducting material by functionalizing the thiolated calix[4]arene (TC4) with AuNPs while retaining the ERGO as an immobilization matrix to stabilize the hybrid material (TC4/AuNPs/ERGO). Regrettably, the formation of a calix[4]arene monolayer is unsatisfactory to appoint a high concentration of target analyte due to the limited accessible cavities, meanwhile the multilayer formation of calix[4]arenes arrangement optimizes the the π-stacking interactions between the adjacent calix[4]arene through non-covalent interactions, hence block the diffusion of target analyte.

In response to this shortcoming, a possible strategy to defeat this issue is by synthesizing a new metal-organic framework with calix[4]arene-based ligands to form a new sensor (C4TCA@MOF/AuNPs/ERGO). The framework formation can elegantly serve the feasibility of forming hierarchically-porous materials with two levels of porosity; the ligand and the structural framework itself, thus significantly improve the analytical measurement caused by the limited accessible cavities of calix[4]arene. Finally, the scope of the study was wrapped up with the development of a portable customized electrochemical device based on the best outstanding performance of fabricated calix[4]arene-based sensor for the determination of anthracene in real water samples.

1.6 Thesis Structure

The thesis consists of 6 chapters and organized as follows. Chapter 1 is the introduction of the thesis which constitutes of research background, problem statements and research motivation, research objectives, novelty of research, and scope of the study. Chapter 2 reviews the relevant available literature on the sources and occurrence of PAHs in water, recent development of electrochemical sensors for electroanalysis of PAHs, challenges and future outlooks. Chapter 3 reports the surface modification of the screen-printed carbon electrode (SPCE) with calix[4]arene-functionalized electrochemically reduced graphene oxide (C4/ERGO) in the selective electrochemical detection of anthracene. Chapter 4 provides data on the development of electrochemical sensor based on thiolated calix[4]arene-functionalized gold nanoparticles with assisted of ERGO (TC4/AuNPs/ERGO) for the selective recognition of anthracene. Chapter 5 describes the fabrication and analytical data of electrochemical sensor based on metal-organic framework-calix[4]arene based ligand (C4TCA@MOF), AuNPs, and ERGO as a sensing platform for electrochemical detection of anthracene (C4TCA@MOF/AuNPs/ERGO). This chapter also presents the integration of portable customized potentiostat based on the best outstanding performance of fabricated calix[4]arene-based sensor for the determination of anthracene in real water samples. Chapter 6 discusses the concluding remarks from the research works, significant finding, and provide the directions for future research.

REFERENCES

Abdel-Haleem, F. M., Gamal, E., Rizk, M. S., El Nashar, R. M., Anis, B., Elnabawy, H. M., . . . Barhoum, A. (2020). t-Butyl calixarene/Fe_2O_3@ MWCNTs composite-based potentiometric sensor for determination of ivabradine hydrochloride in pharmaceutical formulations. *Materials Science and Engineering: C, 116*, 111110.

Abdel-Shafy, H. I., & Mansour, M. S. (2016). A review on polycyclic aromatic hydrocarbons: source, environmental impact, effect on human health and remediation. *Egyptian Journal of Petroleum, 25*(1), 107-123.

Achten, C., & Andersson, J. T. (2015). Overview of polycyclic aromatic compounds (PAC). *Polycyclic aromatic compounds, 35*(2-4), 177-186.

Ahammad, A. S., Islam, T., & Hasan, M. M. (2019). Graphene-based electrochemical sensors for biomedical applications. In *Biomedical Applications of Graphene and 2D Nanomaterials* (pp. 249-282): Elsevier.

Ahmad, A., & Moore, E. (2012). Electrochemical immunosensor modified with self-assembled monolayer of 11-mercaptoundecanoic acid on gold electrodes for detection of benzo[a]pyrene in water. *Analyst, 137*(24), 5839-5844.

Ahmad, R., Mahmoudi, T., Ahn, M.-S., Yoo, J.-Y., & Hahn, Y.-B. (2018). Fabrication of sensitive non-enzymatic nitrite sensor using silver-reduced graphene oxide nanocomposite. *Journal of Colloid and Interface Science*.

Akgol, G., Yildiz, C., Karakus, S., Koc, M., Dogan, M., Turan, K., & Karadayi, K. (2016). The effects of intraperitoneal chemotherapeutic agents on adhesion formation. *European Journal of Gynaecological Oncology, 37*(6), 781-785.

Alexandrov, K., Rojas, M., & Satarug, S. (2010). The critical DNA damage by benzo(a)pyrene in lung tissues of smokers and approaches to preventing its formation. *Toxicology letters, 198*(1), 63-68.

Alhamdow, A., Essig, Y. J., Krais, A. M., Gustavsson, P., Tinnerberg, H., Lindh, C. H., . . . Broberg, K. (2020). Fluorene exposure among PAH-exposed workers is associated with epigenetic markers related to lung cancer. *Occupational and environmental medicine, 77*(7), 488-495.

Ali, D., Verma, A., Mujtaba, F., Dwivedi, A., Hans, R., & Ray, R. (2011). UVB-induced apoptosis and DNA damaging potential of chrysene via reactive oxygen species in human keratinocytes. *Toxicology letters, 204*(2-3), 199-207.

Andersson, J. T., & Achten, C. (2015). Time to say goodbye to the 16 EPA PAHs? Toward an up-to-date use of PACs for environmental purposes. *Polycyclic aromatic compounds, 35*(2-4), 330-354.

Andersson, T. A., Hartonen, K. M., & Riekkola, M.-L. (2005). Solubility of acenaphthene, anthracene, and pyrene in water at 50°C to 300°C. *Journal of Chemical & Engineering Data, 50*(4), 1177-1183.

Antúnez-García, J., Mejía-Rosales, S., Pérez-Tijerina, E., Montejano-Carrizales, J. M., & José-Yacamán, M. (2011). Coalescence and collisions of gold nanoparticles. *Materials, 4*(2), 368-379.

Arcidiacono, S., Bieri, N., Poulikakos, D., & Grigoropoulos, C. (2004). On the coalescence of gold nanoparticles. *International Journal of Multiphase Flow, 30*(7-8), 979-994.

Arey, J., & Atkinson, R. (2003). Photochemical reactions of PAHs in the atmosphere. *PAHs: an ecotoxicological perspective*, 47-63.

Armstrong, B., Hutchinson, E., Unwin, J., & Fletcher, T. (2004). Lung cancer risk after exposure to polycyclic aromatic hydrocarbons: a review and meta-analysis. *Environmental health perspectives, 112*(9), 970-978.

Ashraf, M. W., Taqvi, S. I. H., Solangi, A. R., & Qureshi, U. A. (2012). Distribution and risk assessment of polycyclic aromatic hydrocarbons in vegetables grown in Pakistan. *Journal of Chemistry, 2013*.

Atwood, J. L., Barbour, L. J., Dalgarno, S., Raston, C. L., & Webb, H. R. (2002). Supramolecular assemblies of p-sulfonatocalix[4]arene with aquated trivalent lanthanide ions. *Journal of the Chemical Society, Dalton Transactions*(23), 4351-4356.

Bain, R. E., Gundry, S. W., Wright, J. A., Yang, H., Pedley, S., & Bartram, J. K. (2012). Accounting for water quality in monitoring access to safe drinking-water as part of the Millennium Development Goals: lessons from five countries. *Bulletin of the World Health Organization, 90*, 228-235.

Ballarin, B., Cassani, M. C., Scavetta, E., & Tonelli, D. (2008). Self-assembled gold nanoparticles modified ITO electrodes: The monolayer binder molecule effect. *Electrochimica Acta, 53*(27), 8034-8044.

Bao, L., Sheng, P., Li, J., Wu, S., Cai, Q., & Yao, S. (2012). Surface enhanced Raman spectroscopic detection of polycyclic aromatic hydrocarbons (PAHs) using a gold nanoparticles-modified alginate gel network. *Analyst, 137*(17), 4010-4015.

Barasch, D., Zipori, O., Ringel, I., Ginsburg, I., Samuni, A., & Katzhendler, J. (1999). Novel anthraquinone derivatives with redox-active functional groups capable of producing free radicals by metabolism: are free radicals essential for cytotoxicity? *European journal of medicinal chemistry, 34*(7-8), 597-615.

Barazesh, J. M., Prasse, C., & Sedlak, D. L. (2016). Electrochemical transformation of trace organic contaminants in the presence of halide and carbonate ions. *Environmental science & technology, 50*(18), 10143-10152.

Bard, A. J., & Faulkner, L. R. (2001). Fundamentals and applications. *Electrochemical methods, 2*(482), 580-632.

Barón-Jaimez, J., Joya, M., & Barba-Ortega, J. (2013). *Anodic stripping voltammetry–ASV for determination of heavy metals.* Paper presented at the Journal of Physics: Conference Series.

Berge, G., Mollerup, S., Øvrebø, S., Hewer, A., Phillips, D. H., Eilertsen, E., & Haugen, A. (2004). Role of estrogen receptor in regulation of polycyclic aromatic hydrocarbon metabolic activation in lung. *Lung Cancer, 45*(3), 289-297.

Bhadra, S., Khastgir, D., Singha, N. K., & Lee, J. H. (2009). Progress in preparation, processing and applications of polyaniline. *Progress in polymer science, 34*(8), 783-810.

Boikanyo, D., Adekunle, A. S., & Ebenso, E. E. (2016). *Electrochemical Study of Pyrene on Glassy Carbon Electrode Modified with Metal-Oxide Nanoparticles and Graphene Oxide/Multi-Walled Carbon Nanotubes Nanoplatform.* Paper presented at the Journal of Nano Research.

Bonanni, A., Pumera, M., & Miyahara, Y. (2011). Influence of gold nanoparticle size (2–50 nm) upon its electrochemical behavior: an electrochemical impedance spectroscopic and voltammetric study. *Physical Chemistry Chemical Physics, 13*(11), 4980-4986.

Boonyatumanond, R., Murakami, M., Wattayakorn, G., Togo, A., & Takada, H. (2007). Sources of polycyclic aromatic hydrocarbons (PAHs) in street dust in a tropical Asian mega-city, Bangkok, Thailand. *Science of the Total Environment, 384*(1-3), 420-432.

Boström, C.-E., Gerde, P., Hanberg, A., Jernström, B., Johansson, C., Kyrklund, T., . . . Westerholm, R. (2002). Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air. *Environmental health perspectives, 110*(suppl 3), 451-488.

Boudjema, L., Long, J., Petitjean, H., Larionova, J., Guari, Y., Trens, P., & Salles, F. (2020). Adsorption of volatile organic compounds by ZIF-8, Cu-BTC and a Prussian blue analogue: A comparative study. *Inorganica Chimica Acta, 501*, 119316.

Bouvrette, P., Hrapovic, S., Male, K. B., & Luong, J. H. (2006). Analysis of the 16 Environmental Protection Agency priority polycyclic aromatic hydrocarbons by high performance liquid chromatography-oxidized diamond film electrodes. *Journal of Chromatography A, 1103*(2), 248-256.

Brett, C. M. (1999). Electroanalytical techniques for the future: the challenges of miniaturization and of real-time measurements. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis, 11*(14), 1013-1016.

Brett, C. M. (2001). Electrochemical sensors for environmental monitoring. Strategy and examples. *Pure and applied chemistry, 73*(12), 1969-1977.

Broniatowski, M., Binczycka, M., Wójcik, A., Flasiński, M., & Wydro, P. (2017). Polycyclic aromatic hydrocarbons in model bacterial membranes–Langmuir monolayer studies. *Biochimica et Biophysica Acta (BBA)-Biomembranes, 1859*(12), 2402-2412.

Brookes, P., & Lawley, P. D. (1964). Evidence for the binding of polynuclear aromatic hydrocarbons to the nucleic acids of mouse skin: relation between carcinogenic power of hydrocarbons and their binding to deoxyribonucleic acid. *nature, 202*(4934), 781.

Brown, K. L. (2018). Electrochemical Preparation and Characterization of Chemically Modified Electrodes. In *Voltammetry*: IntechOpen.

Burchiel, S. W., & Luster, M. I. (2001). Signaling by environmental polycyclic aromatic hydrocarbons in human lymphocytes. *Clinical Immunology, 98*(1), 2-10.

Butler, K. T., Hendon, C. H., & Walsh, A. (2014). Electronic chemical potentials of porous metal–organic frameworks. *Journal of the American Chemical Society, 136*(7), 2703-2706.

Cao, Y., Ma, Y., Wang, T., Wang, X., Huo, Q., & Liu, Y. (2016). Facile fabricating hierarchically porous metal–organic frameworks via a template-free strategy. *Crystal Growth & Design, 16*(1), 504-510.

Chen, X., Wang, Y., Zhang, Y., Chen, Z., Liu, Y., Li, Z., & Li, J. (2014). Sensitive electrochemical aptamer biosensor for dynamic cell surface N-glycan evaluation featuring multivalent recognition and signal amplification on a dendrimer–graphene electrode interface. *Analytical chemistry, 86*(9), 4278-4286.

Chen, Z., Ren, W., Gao, L., Liu, B., Pei, S., & Cheng, H.-M. (2011). Three-dimensional flexible and conductive interconnected graphene networks grown by chemical vapour deposition. *Nature materials, 10*(6), 424.

Cherng, S.-H., Lin, P., Yang, J.-L., Hsu, S.-L., & Lee, H. (2001). Benzo [g, h, i] perylene synergistically transactivates benzo [a] pyrene-induced CYP1A1 gene expression by aryl hydrocarbon receptor pathway. *Toxicology and applied pharmacology, 170*(1), 63-68.

Committee, D. G. A. (2015). Scientific report of the 2015 Dietary Guidelines Advisory Committee: advisory report to the Secretary of Health and Human Services and the Secretary of Agriculture. *Agricultural Research Service*, 2019-2009.

Comninellis, C. (1994). Electrocatalysis in the electrochemical conversion/combustion of organic pollutants for waste water treatment. *Electrochimica Acta, 39*(11-12), 1857-1862.

Cordeiro, D. S., & Corio, P. (2009). Electrochemical and photocatalytic reactions of polycyclic aromatic hydrocarbons investigated by raman spectroscopy. *Journal of the Brazilian Chemical Society, 20*(1), 80-87.

Costa, J., Sant'Ana, A., Corio, P., & Temperini, M. (2006). Chemical analysis of polycyclic aromatic hydrocarbons by surface-enhanced Raman spectroscopy. *Talanta, 70*(5), 1011-1016.

Creager, S. (2007). Solvents and supporting electrolytes. In *Handbook of electrochemistry* (pp. 57-72): Elsevier.

Crowther, R. A., DeRosier, D., & Klug, A. (1970). The reconstruction of a three-dimensional structure from projections and its application to electron microscopy. *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences, 317*(1530), 319-340.

D'Alessandro, D. M., Kanga, J. R., & Caddy, J. S. (2011). Towards conducting metal-organic frameworks. *Australian Journal of Chemistry, 64*(6), 718-722.

Darvina, L., & Supian, F. L. (2019). Calix[4]arene and calix[8]arene Langmuir films: surface studies, optical and structural characterizations. *Int. J. Innov. Technol. Explor. Eng, 8*, 80-85.

Dat, N.-D., & Chang, M. B. (2017). Review on characteristics of PAHs in atmosphere, anthropogenic sources and control technologies. *Science of the Total Environment, 609*, 682-693.

De Flora, S., Scarfì, S., Izzotti, A., D'Agostini, F., Chang, C.-C., Bagnasco, M., . . . Trosko, J. E. (2006). Induction by 7, 12-dimethylbenz(a)anthracene of molecular and biochemical alterations in transformed human mammary epithelial stem cells, and protection by N-acetylcysteine. *International journal of oncology, 29*(3), 521-529.

De La Escosura-Muñiz, A., Parolo, C., Maran, F., & Mekoçi, A. (2011). Size-dependent direct electrochemical detection of gold nanoparticles: application in magnetoimmunoassays. *Nanoscale, 3*(8), 3350-3356.

de Souza Machado, A. A., Hoff, M. L. M., Klein, R. D., Cordeiro, G. J., Avila, J. M. L., Costa, P. G., & Bianchini, A. (2014). Oxidative stress and DNA damage responses to phenanthrene exposure in the estuarine guppy Poecilia vivipara. *Marine Environmental Research, 98*, 96-105.

Del Carlo, M., Di Marcello, M., Perugini, M., Ponzielli, V., Sergi, M., Mascini, M., & Compagnone, D. (2008). Electrochemical DNA biosensor for polycyclic aromatic hydrocarbon detection. *Microchimica Acta, 163*(3-4), 163-169.

Dhawan, S., Kumar, D., Ram, M., Chandra, S., & Trivedi, D. (1997). Application of conducting polyaniline as sensor material for ammonia. *Sensors and Actuators B: Chemical, 40*(2-3), 99-103.

Dimashki, M., Lim, L. H., Harrison, R. M., & Harrad, S. (2001). Temporal trends, temperature dependence, and relative reactivity of atmospheric polycyclic aromatic hydrocarbons. *Environmental science & technology, 35*(11), 2264-2267.

Directive, C. (1998). On the quality of water intended for human consumption. *Official Journal of the European Communities, 330*, 32-54.

Dorothy, M. (1982). *Proceedings 1981 International Conference on Residential Solid Fuels: environmental impacts and solutions, June 1-4, 1981, Portland Hilton, Portland, Oregon, USA.* Paper presented at the Oregon Graduate Center (USA). International Conference on Residential Solid Fuels. Portland, Oregon (USA). 1981.

Dost, K., & İdeli, C. (2012). Determination of polycyclic aromatic hydrocarbons in edible oils and barbecued food by HPLC/UV–Vis detection. *Food Chemistry, 133*(1), 193-199.

Driskill, A. K., Alvey, J., Dotson, A. D., & Tomco, P. L. (2018). Monitoring polycyclic aromatic hydrocarbon (PAH) attenuation in Arctic waters using fluorescence spectroscopy. *Cold Regions Science and Technology, 145*, 76-85.

Drogui, P., Blais, J.-F., & Mercier, G. (2007). Review of electrochemical technologies for environmental applications. *Recent patents on engineering, 1*(3), 257-272.

Du, C., Hu, Y., Li, Y., Fan, L., & Li, X. (2015). Electrochemical detection of benzo(a)pyrene in acetonitrile–water binary medium. *Talanta, 138*, 46-51.

Ehli, C., Rahman, G. A., Jux, N., Balbinot, D., Guldi, D. M., Paolucci, F., . . . Zerbetto, F. (2006). Interactions in single wall carbon nanotubes/pyrene/porphyrin nanohybrids. *Journal of the American Chemical Society, 128*(34), 11222-11231.

Emiru, T. F., & Ayele, D. W. (2017). Controlled synthesis, characterization and reduction of graphene oxide: A convenient method for large scale production. *Egyptian Journal of Basic and Applied Sciences, 4*(1), 74-79.

Endo, S., Pfennigsdorff, A., & Goss, K.-U. (2012). Salting-out effect in aqueous NaCl solutions: trends with size and polarity of solute molecules. *Environmental science & technology, 46*(3), 1496-1503.

Esken, D., Turner, S., Lebedev, O. I., Van Tendeloo, G., & Fischer, R. A. (2010). Au@ZIFs: stabilization and encapsulation of cavity-size matching gold clusters inside functionalized zeolite imidazolate frameworks, ZIFs. *Chemistry of materials, 22*(23), 6393-6401.

Fang, G.-C., Wu, Y.-S., Chen, J.-C., Chang, C.-N., & Ho, T.-T. (2006). Characteristic of polycyclic aromatic hydrocarbon concentrations and source identification for fine and coarse particulates at Taichung Harbor near Taiwan Strait during 2004–2005. *Science of the Total Environment, 366*(2-3), 729-738.

Fang, X., Liu, J., Wang, J., Zhao, H., Ren, H., & Li, Z. (2017). Dual signal amplification strategy of Au nanopaticles/ZnO nanorods hybridized reduced graphene nanosheet and multienzyme functionalized Au@ ZnO composites for ultrasensitive electrochemical detection of tumor biomarker. *Biosensors and Bioelectronics, 97*, 218-225.

Fleger, Y., & Rosenbluh, M. (2009). Surface plasmons and surface enhanced Raman spectra of aggregated and alloyed gold-silver nanoparticles. *International Journal of Optics, 2009*.

Fojta, M. (2002). Electrochemical sensors for DNA interactions and damage. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis, 14*(21), 1449-1463.

Fojta, M., Havran, L., Fulnečková, J., & Kubičárová, T. (2000). Adsorptive transfer stripping AC voltammetry of DNA complexes with intercalators. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis, 12*(12), 926-934.

Furukawa, H., & Cordova, K. E. (2013). O, Keeffe, M.; Yaghi, OM The chemistry and applications of metal-organic frameworks. *Science, 341*(6149), 1230444.

Gamboa, R. T., Gamboa, A. R., Bravo, A. H., & Ostrosky, W. P. (2008). Genotoxicity in child populations exposed to polycyclic aromatic hydrocarbons (PAHs) in the air from Tabasco, Mexico. *International Journal of Environmental Research and Public Health, 5*(5), 349-355.

Gandini, D., Comninellis, C., Tahar, N. B., & Savall, A. (1998). Électrodépollution: traitement électrochimique des eaux résiduaires chargées en matières organiques toxiques. *Actualité Chimique, 10*, 68-73.

Garcia-Segura, S., Ocon, J. D., & Chong, M. N. (2018). Electrochemical oxidation remediation of real wastewater effluents—a review. *Process Safety and Environmental Protection, 113*, 48-67.

Gehle, K. (2009). Agency for Toxic Substances and Disease Registry (ATSDR) Case Studies in Environmental Medicine Toxicity of Polycyclic Aromatic Hydrocarbons (PAHs). In: USA Department of Health and Human Services Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine.

German, N., & Armalis, S. (2012). Voltammetric determination of naphthalene, fluorene and anthracene using mixed water-organic solvent media. *chemija, 23*(2).

Ghadimi, H., Tehrani, R. M., Ali, A. S. M., Mohamed, N., & Ab Ghani, S. (2013). Sensitive voltammetric determination of paracetamol by poly (4-vinylpyridine)/multiwalled carbon nanotubes modified glassy carbon electrode. *Analytica chimica acta, 765*, 70-76.

Ghadimi, H., Tehrani, R. M., Basirun, W. J., Ab Aziz, N. J., Mohamed, N., & Ab Ghani, S. (2016). Electrochemical determination of aspirin and caffeine at MWCNTs-poly-4-vinylpyridine composite modified electrode. *Journal of the Taiwan Institute of Chemical Engineers, 65*, 101-109.

Ghanbari, M. H., Shahdost-Fard, F., Salehzadeh, H., Ganjali, M. R., Iman, M., Rahimi-Nasrabadi, M., & Ahmadi, F. (2019). A nanocomposite prepared from reduced graphene oxide, gold nanoparticles and poly (2-amino-5-mercapto-1, 3, 4-thiadiazole) for use in an electrochemical sensor for doxorubicin. *Microchimica Acta, 186*(9), 1-10.

Gong, P., Wang, X., Sheng, J., Wang, H., Yuan, X., He, Y., . . . Yao, T. (2018). Seasonal variations and sources of atmospheric polycyclic aromatic hydrocarbons and organochlorine compounds in a high-altitude city: Evidence from four-year observations. *Environmental Pollution, 233*, 1188-1197.

Guidi, G. D., Librando, V., Minniti, Z., Bolzacchini, E., Perrini, G., Bracchitta, G., . . . Catalfo, A. (2012). The PAH and nitro-PAH concentration profiles in size-segregated urban particulate matter and soil in traffic-related sites in Catania, Italy. *Polycyclic aromatic compounds, 32*(4), 439-456.

Gupta, H. (2017). PAH determination in effluent and sludge samples of paper industry. *Environmental Technology & Innovation*.

Gupta, R., Dyer, M., & Weimer, W. (2002). Preparation and characterization of surface plasmon resonance tunable gold and silver films. *Journal of Applied Physics, 92*(9), 5264-5271.

Gutsche, C. D. (2008). *Calixarenes: an introduction*: Royal Society of Chemistry.

Gutsche, C. D., & Nam, K. C. (1988). Calixarenes. 22. Synthesis, properties, and metal complexation of aminocalixarenes. *Journal of the American Chemical Society, 110*(18), 6153-6162.

Haiba, N., & Hassan, I. (2018). Monitoring and assessment of polycyclic aromatic hydrocarbons (PAHs) in the atmosphere of Alexandria city, Egypt. *Polycyclic aromatic compounds, 38*(3), 219-230.

Haiss, W., Thanh, N. T., Aveyard, J., & Fernig, D. G. (2007). Determination of size and concentration of gold nanoparticles from UV− Vis spectra. *Analytical chemistry, 79*(11), 4215-4221.

Halsall, C. J., Barrie, L. A., Fellin, P., Muir, D., Billeck, B., Lockhart, L., . . . Pastukhov, B. (1997). Spatial and temporal variation of polycyclic aromatic hydrocarbons in the Arctic atmosphere. *Environmental science & technology, 31*(12), 3593-3599.

Hanna, T. A., Liu, L., Angeles-Boza, A. M., Kou, X., Gutsche, C. D., Ejsmont, K., . . . Rheingold, A. L. (2003). Synthesis, structures, and conformational characteristics of calixarene monoanions and dianions. *Journal of the American Chemical Society, 125*(20), 6228-6238.

Hanssen, B. L., Siraj, S., & Wong, D. K. (2016). Recent strategies to minimise fouling in electrochemical detection systems. *Reviews in Analytical Chemistry, 35*(1), 1-28.

Harrison, R. M., Alam, M. S., Dang, J., Basahi, J., Alghamdi, M. A., Ismail, I., . . . Hassan, I. (2016). Influence of petrochemical installations upon PAH concentrations at sites in Western Saudi Arabia. *Atmospheric Pollution Research, 7*(6), 954-960.

Heitkamp, M. A., & Cerniglia, C. E. (1988). Mineralization of polycyclic aromatic hydrocarbons by a bacterium isolated from sediment below an oil field. *Applied and environmental microbiology, 54*(6), 1612-1614.

Hendon, C. H., Tiana, D., & Walsh, A. (2012). Conductive metal–organic frameworks and networks: fact or fantasy? *Physical Chemistry Chemical Physics, 14*(38), 13120-13132.

Hirai, K., Furukawa, S., Kondo, M., Uehara, H., Sakata, O., & Kitagawa, S. (2011). Sequential functionalization of porous coordination polymer crystals. *Angewandte Chemie, 123*(35), 8207-8211.

Hosseini, H., Ahmar, H., Dehghani, A., Bagheri, A., Fakhari, A. R., & Amini, M. M. (2013). Au-SH-SiO_2 nanoparticles supported on metal-organic framework (Au-SH-SiO_2@ Cu-MOF) as a sensor for electrocatalytic oxidation and determination of hydrazine. *Electrochimica Acta, 88*, 301-309.

Huang, X., Qi, X., Boey, F., & Zhang, H. (2012). Graphene-based composites. *Chemical Society Reviews, 41*(2), 666-686.

Itoh, N., Aoyagi, Y., & Yarita, T. (2006). Optimization of the dopant for the trace determination of polycyclic aromatic hydrocarbons by liquid chromatography/dopant-assisted atmospheric-pressure photoionization/mass spectrometry. *Journal of Chromatography A, 1131*(1-2), 285-288.

Jacob, J., & Seidel, A. (2002). Biomonitoring of polycyclic aromatic hydrocarbons in human urine. *Journal of Chromatography B, 778*(1-2), 31-47.

Ji, L., Chen, W., Xu, Z., Zheng, S., & Zhu, D. (2013). Graphene nanosheets and graphite oxide as promising adsorbents for removal of organic contaminants from aqueous solution. *Journal of environmental quality, 42*(1), 191-198.

Jian, J.-M., Liu, Y.-Y., Zhang, Y.-L., Guo, X.-S., & Cai, Q. (2013). Fast and sensitive detection of Pb^{2+} in foods using disposable screen-printed electrode modified by reduced graphene oxide. *Sensors, 13*(10), 13063-13075.

Jiang, S., Hua, E., Liang, M., Liu, B., & Xie, G. (2013). A novel immunosensor for detecting toxoplasma gondii-specific IgM based on goldmag nanoparticles and graphene sheets. *Colloids and Surfaces B: Biointerfaces, 101*, 481-486.

Käfferlein, H. U., Marczynski, B., Mensing, T., & Brüning, T. (2010). Albumin and hemoglobin adducts of benzo [a] pyrene in humans—analytical methods, exposure assessment, and recommendations for future directions. *Critical reviews in toxicology, 40*(2), 126-150.

Kang, S. K., Chung, T. D., & Kim, H. (2000). Electrochemical recognition of Ca^{2+} ion in basic aqueous media using quinone-derivatized calix[4]arene. *Electrochimica Acta, 45*(18), 2939-2943.

Keith, L., & Telliard, W. (1979). ES&T special report: priority pollutants: Ia perspective view. *Environmental science & technology, 13*(4), 416-423.

Kerdelhué, B., Forest, C., & Coumoul, X. (2016). Dimethyl-benz(a)anthracene: a mammary carcinogen and a neuroendocrine disruptor. *Biochimie open, 3*, 49-55.

Killin, R. K., Simonich, S. L., Jaffe, D. A., DeForest, C. L., & Wilson, G. R. (2004). Transpacific and regional atmospheric transport of anthropogenic semivolatile organic compounds to Cheeka Peak Observatory during the spring of 2002. *Journal of Geophysical Research: Atmospheres, 109*(D23).

Kim, J., Cote, L. J., Kim, F., Yuan, W., Shull, K. R., & Huang, J. (2010). Graphene oxide sheets at interfaces. *Journal of the American Chemical Society, 132*(23), 8180-8186.

Kim, J., Ohki, A., Ueki, R., Ishizuka, T., Shimotashiro, T., & Maeda, S. (1999). Cesium-ion selective electrodes based on calix[4]arene dibenzocrown ethers. *Talanta, 48*(3), 705-710.

Kimling, J., Maier, M., Okenve, B., Kotaidis, V., Ballot, H., & Plech, A. (2006). Turkevich method for gold nanoparticle synthesis revisited. *The Journal of Physical Chemistry B, 110*(32), 15700-15707.

Kiranmai, S., Reddy, Y. V. M., Venu, M., Madhuri, C., Anitha, K., Madhavi, G., & Reddy, A. V. (2017). Determination of Terazosin by using poly (Congo red) modified carbon paste electrode. *Anal. Bioanal. Electrochem., 9*(2), 154-163.

Klaassen, C. D., & Amdur, M. O. (2013). *Casarett and Doull's toxicology: the basic science of poisons* (Vol. 1236): McGraw-Hill New York.

Klajnert, B., & Bryszewska, M. (2001). Dendrimers: properties and applications.

Kubo, T., Bai, W., Nagae, M., & Takao, Y. (2020). Seasonal Fluctuation of Polycyclic Aromatic Hydrocarbons and Aerosol Genotoxicity in Long-Range Transported Air Mass Observed at the Western End of Japan. *International Journal of Environmental Research and Public Health, 17*(4), 1210.

Kudin, K. N., Ozbas, B., Schniepp, H. C., Prud'Homme, R. K., Aksay, I. A., & Car, R. (2008). Raman spectra of graphite oxide and functionalized graphene sheets. *Nano letters, 8*(1), 36-41.

Kumar, D. R., Kesavan, S., Baynosa, M. L., & Shim, J.-J. (2017). 3, 5-Diamino-1, 2, 4-triazole@ electrochemically reduced graphene oxide film modified electrode for the electrochemical determination of 4-nitrophenol. *Electrochimica Acta, 246*, 1131-1140.

Kung, C.-W., Han, P.-C., Chuang, C.-H., & Wu, K. C.-W. (2019). Electronically conductive metal–organic framework-based materials. *APL Materials, 7*(11), 110902.

Kwack, S. J., & Mu Lee, B. (2000). Correlation between DNA or protein adducts and benzo[a]pyrene diol epoxide I–triglyceride adduct detected in vitro and in vivo. *Carcinogenesis, 21*(4), 629-632.

Lang, C., Tao, S., Zhang, G., Fu, J., & Simonich, S. (2007). Outflow of polycyclic aromatic hydrocarbons from Guangdong, Southern China. *Environmental science & technology, 41*(24), 8370-8375.

Latif-ur-Rahman, Shah, A., Han, C., & Jan, A. K. (2020). Monitoring of Anthracene Using Nanoscale Au–Cu Bimetallic Alloy Nanoparticles Synthesized with Various Compositions. *ACS Omega*.

LaVole, E. J., Amin, S., Hecht, S. S., Furuya, K., & Hoffmann, D. (1982). Tumour initiating activity of dihydrodiols of benzo [b] fluoranthene, benzo [j] fluoranthene, and benzo [k] fluoranthene. *Carcinogenesis, 3*(1), 49-52.

Lee, E., Kim, Y., Heo, J., & Park, K.-M. (2015). 3D metal–organic framework based on a lower-rim acid-functionalized calix[4]arene: crystal-to-crystal transformation upon lattice solvent removal. *Crystal Growth & Design, 15*(8), 3556-3560.

Lee, J. Y., Kim, Y. P., Kang, C. H., Ghim, Y. S., & Kaneyasu, N. (2006). Temporal trend and long-range transport of particulate polycyclic aromatic hydrocarbons at Gosan in northeast Asia between 2001 and 2004. *Journal of Geophysical Research: Atmospheres, 111*(D11).

Leyton, P., Sanchez-Cortes, S., Garcia-Ramos, J., Domingo, C., Campos-Vallette, M., Saitz, C., & Clavijo, R. (2004). Selective molecular recognition of polycyclic aromatic hydrocarbons (PAHs) on calix[4]arene-functionalized Ag nanoparticles by surface-enhanced Raman scattering. *The Journal of Physical Chemistry B, 108*(45), 17484-17490.

Li, D., Wang, M., Dhingra, K., & Hittelman, W. N. (1996). Aromatic DNA adducts in adjacent tissues of breast cancer patients: clues to breast cancer etiology. *Cancer research, 56*(2), 287-293.

Li, G., Xia, L., Dong, J., Chen, Y., & Li, Y. (2019). Metal-organic frameworks 10. *Solid-Phase Extraction*, 285.

Li, H., & Qu, F. (2007). Selective inclusion of polycyclic aromatic hydrocarbons (PAHs) on calixarene coated silica nanospheres englobed with CdTe nanocrystals. *Journal of Materials Chemistry, 17*(33), 3536-3544.

Li, J., & Lin, X.-Q. (2007). Electrodeposition of gold nanoclusters on overoxidized polypyrrole film modified glassy carbon electrode and its application for the simultaneous determination of epinephrine and uric acid under coexistence of ascorbic acid. *Analytica chimica acta, 596*(2), 222-230.

Li, Q., Xu, X., Sen-Chun, L. F., & Wang, X. (2006). Determination of trace PAHs in seawater and sediment pore-water by solid-phase microextraction (SPME) coupled with GC/MS. *Science in China Series B: Chemistry, 49*(6), 481-491.

Li, Y., Huangfu, C., Du, H., Liu, W., Li, Y., & Ye, J. (2013). Electrochemical behavior of metal–organic framework MIL-101 modified carbon paste electrode: an excellent candidate for electroanalysis. *Journal of Electroanalytical Chemistry, 709*, 65-69.

Li, Y., Li, Y., Wang, Y., Ma, G., Liu, X., Li, Y., & Soar, J. (2020). Application of zeolitic imidazolate frameworks (ZIF-8)/ionic liquid composites modified nano-carbon paste electrode as sensor for electroanalytical sensing of 1-hydroxypyrene. *Microchemical Journal*, 105433.

Li, Z., Porter, E. N., Sjödin, A., Needham, L. L., Lee, S., Russell, A. G., & Mulholland, J. A. (2009). Characterization of $PM_{2.5}$-bound polycyclic aromatic hydrocarbons in Atlanta—seasonal variations at urban, suburban, and rural ambient air monitoring sites. *Atmospheric Environment, 43*(27), 4187-4193.

Liao, W., Liu, C., Wang, X., Zhu, G., Zhao, X., & Zhang, H. (2009). 3D metal–organic frameworks incorporating water-soluble tetra-p-sulfonatocalix[4]arene. *CrystEngComm, 11*(11), 2282-2284.

Lin, M., Liu, Y., Sun, Z., Zhang, S., Yang, Z., & Ni, C. (2012). Electrochemical immunoassay of benzo[a]pyrene based on dual amplification strategy of electron-accelerated Fe_3O_4/polyaniline platform and multi-enzyme-functionalized carbon sphere label. *Analytica chimica acta, 722*, 100-106.

Ling, J. L. W., & Ab Ghani, S. (2013). Poly (4-vinylpyridine-co-aniline)-modified electrode—synthesis, characterization, and application as cadmium (II) ion sensor. *Journal of Solid State Electrochemistry, 17*(3), 681-690.

Liu, D., Xu, Y., Chaemfa, C., Tian, C., Li, J., Luo, C., & Zhang, G. (2014). Concentrations, seasonal variations, and outflow of atmospheric polycyclic aromatic hydrocarbons (PAHs) at Ningbo site, Eastern China. *Atmospheric Pollution Research, 5*(2), 203-209.

Liu, L.-b., Yan, L., LIN, J.-m., Ning, T., Hayakawa, K., & Maeda, T. (2007). Development of analytical methods for polycyclic aromatic hydrocarbons (PAHs) in airborne particulates: a review. *Journal of Environmental Sciences, 19*(1), 1-11.

Liu, S., Wei, M., Zheng, X., Xu, S., Xia, F., & Zhou, C. (2015). Alizarin red S functionalized mesoporous silica modified glassy carbon electrode for electrochemical determination of anthracene. *Electrochimica Acta, 160*, 108-113.

Liu, S., Wei, M., Zheng, X., Xu, S., & Zhou, C. (2014). Highly sensitive and selective sensing platform based on π–π interaction between tricyclic aromatic hydrocarbons with thionine–graphene composite. *Analytica chimica acta, 826*, 21-27.

Ma, J.-K., Saad Eldin, W. F., El-Ghareeb, W. R., Elhelaly, A. E., Khedr, M. H., Li, X., & Huang, X.-C. (2019). Effects of Pyrene on Human Liver HepG2 Cells: Cytotoxicity, Oxidative Stress, and Transcriptomic Changes in Xenobiotic Metabolizing Enzymes and Inflammatory Markers with Protection Trial Using Lycopene. *BioMed research international, 2019*.

Ma, Q., Zong, J., Cheng, Y., Alfredo, A. L., Jia, Y., Chen, G., & Sun, C. (2020). Modeling study on absorption-adsorption of gas in ZIF-8/absorbent slurry system. *Fluid Phase Equilibria, 506*, 112396.

Ma, W., Jiang, Q., Yu, P., Yang, L., & Mao, L. (2013). Zeolitic imidazolate framework-based electrochemical biosensor for in vivo electrochemical measurements. *Analytical chemistry, 85*(15), 7550-7557.

Machado, B. F., & Serp, P. (2012). Graphene-based materials for catalysis. *Catalysis Science & Technology, 2*(1), 54-75.

Mahler, B. J., Van Metre, P. C., Bashara, T. J., Wilson, J. T., & Johns, D. A. (2005). Parking lot sealcoat: an unrecognized source of urban polycyclic aromatic hydrocarbons. *Environmental science & technology, 39*(15), 5560-5566.

Mailu, S. N., Waryo, T. T., Ndangili, P. M., Ngece, F. R., Baleg, A. A., Baker, P. G., & Iwuoha, E. I. (2010). Determination of anthracene on Ag-Au alloy nanoparticles/overoxidized-polypyrrole composite modified glassy carbon electrodes. *Sensors, 10*(10), 9449-9465.

Makelane, H., Waryo, T., Feleni, U., & Iwuoha, E. (2019). Dendritic copolymer electrode for second harmonic alternating current voltammetric signalling of pyrene in oil-polluted wastewater. *Talanta, 196*, 204-210.

Makelane, H. R., John, S. V., Waryo, T. T., Baleg, A., Mayedwa, N., Rassie, C., . . . Iwuoha, E. I. (2016). AC voltammetric transductions and sensor application of a novel dendritic poly (propylene thiophenoimine)-co-poly (3-hexylthiophene) star co-polymer. *Sensors and Actuators B: Chemical, 227*, 320-327.

Malik, A. I., Rowan-Carroll, A., Williams, A., Lemieux, C. L., Long, A. S., Arlt, V. M., . . . Yauk, C. L. (2013). Hepatic genotoxicity and toxicogenomic responses in Muta™ Mouse males treated with dibenz [a, h] anthracene. *Mutagenesis, 28*(5), 543-554.

Manica, D. P., Mitsumori, Y., & Ewing, A. G. (2003). Characterization of electrode fouling and surface regeneration for a platinum electrode on an electrophoresis microchip. *Analytical chemistry, 75*(17), 4572-4577.

Manoli, E., Kouras, A., & Samara, C. (2004). Profile analysis of ambient and source emitted particle-bound polycyclic aromatic hydrocarbons from three sites in northern Greece. *Chemosphere, 56*(9), 867-878.

Manoli, E., & Samara, C. (1999). Polycyclic aromatic hydrocarbons in natural waters: sources, occurrence and analysis. *TrAC Trends in Analytical Chemistry, 18*(6), 417-428.

Mathieu-Scheers, E., Bouden, S., Grillot, C., Nicolle, J., Warmont, F., Bertagna, V., . . . Vautrin-Ul, C. (2019). Trace anthracene electrochemical detection based on electropolymerized-molecularly imprinted polypyrrole modified glassy carbon electrode. *Journal of Electroanalytical Chemistry, 848*, 113253.

Metre, P. C. V., Mahler, B. J., & Wilson, J. T. (2009). PAHs underfoot: contaminated dust from coal-tar sealcoated pavement is widespread in the United States. *Environmental science & technology, 43*(1), 20-25.

Mishra, G. K., Barfidokht, A., Tehrani, F., & Mishra, R. K. (2018). Food safety analysis using electrochemical biosensors. *Foods, 7*(9), 141.

Monzó, J., Insua, I., Fernandez-Trillo, F., & Rodriguez, P. (2015). Fundamentals, achievements and challenges in the electrochemical sensing of pathogens. *Analyst, 140*(21), 7116-7128.

Morao, A., Lopes, A., de Amorim, M. P., & Gonçalves, I. (2004). Degradation of mixtures of phenols using boron doped diamond electrodes for wastewater treatment. *Electrochimica Acta, 49*(9-10), 1587-1595.

Moreira, F. C., Boaventura, R. A., Brillas, E., & Vilar, V. J. (2017). Electrochemical advanced oxidation processes: a review on their application to synthetic and real wastewaters. *Applied Catalysis B: Environmental, 202*, 217-261.

Morris, J., & Seifter, E. (1992). The role of aromatic hydrocarbons in the genesis of breast cancer. *Medical hypotheses, 38*(3), 177-184.

Mostafa, E., Reinsberg, P., Garcia-Segura, S., & Baltruschat, H. (2018). Chlorine species evolution during electrochlorination on boron-doped diamond anodes: In-situ electrogeneration of Cl_2, Cl_2O and ClO_2. *Electrochimica Acta, 281*, 831-840.

Munawar, H., Mankar, J. S., Sharma, M. D., Garcia-Cruz, A., Fernandes, L. A. L., Peacock, M., & Krupadam, R. J. (2020). Highly selective electrochemical nanofilm sensor for detection of carcinogenic PAHs in environmental samples. *Talanta*, 121273.

Mustafa, M. (2011). The Environmental Quality Act 1974: A significant legal instrument for implementing environmental policy directives of Malaysia. *IIUM Law Journal, 19*(1), 1.

Mutihac, L., Lee, J. H., Kim, J. S., & Vicens, J. (2011). Recognition of amino acids by functionalized calixarenes. *Chemical Society Reviews, 40*(5), 2777-2796.

Nagy, A. S., Szabó, J., & Vass, I. (2013). Occurrence and distribution of polycyclic aromatic hydrocarbons in surface water of the Raba River, Hungary. *Journal of Environmental Science and Health, Part A, 48*(10), 1190-1200.

Nasher, E., Heng, L. Y., Zakaria, Z., & Surif, S. (2013). Concentrations and sources of polycyclic aromatic hydrocarbons in the seawater around Langkawi Island, Malaysia. *Journal of Chemistry, 2013*.

Nasr, I., Arief, M., Abdel-Aleem, A., & Malhat, F. (2010). Polycyclic aromatic hydrocarbons (PAHs) in aquatic environment at El Menofiya Governorate, Egypt. *Journal of Applied Sciences Research, 6*(1), 13-21.

Nazario, C. E., Silva, M. R., Franco, M. S., & Lanças, F. M. (2015). Evolution in miniaturized column liquid chromatography instrumentation and applications: An overview. *Journal of Chromatography A, 1421*, 18-37.

Neff, J. M. (1979). Polycyclic aromatic hydrocarbons in the aquatic environment. *Biological Conservation, 18:1*.

Ngah, M., Hashim, M., Nayan, N., Said, Z. M., & Ibrahim, M. H. (2012). Marine pollution trend analysis of tourism beach in Peninsular Malaysia. *World Applied Sciences Journal, 17*(10), 1238-1245.

Ni, Y., Wang, P., Song, H., Lin, X., & Kokot, S. (2014). Electrochemical detection of benzo(a)pyrene and related DNA damage using DNA/hemin/nafion–graphene biosensor. *Analytica chimica acta, 821*, 34-40.

Ostojić, J., Herenda, S., Bešić, Z., Miloš, M., & Galić, B. (2017). Advantages of an electrochemical method compared to the spectrophotometric kinetic study of peroxidase inhibition by boroxine derivative. *Molecules, 22*(7), 1120.

Paatero, P., & Tapper, U. (1994). Positive matrix factorization: A non-negative factor model with optimal utilization of error estimates of data values. *Environmetrics, 5*(2), 111-126.

Paddon, C. A., Banks, C. E., Davies, I. G., & Compton, R. G. (2006). Oxidation of anthracene on platinum macro-and micro-electrodes: Sonoelectrochemical, cryoelectrochemical and sonocryoelectrochemical studies. *Ultrasonics sonochemistry, 13*(2), 126-132.

Padros, J., & Pelletier, E. (2000). In vivo formation of (+)-anti-benzo[a]pyrene diol-epoxide–plasma albumin adducts in fish. *Marine Environmental Research, 50*(1-5), 347-351.

Pang, Y., Huang, Y., Li, W., Feng, L., & Shen, X. (2019). Conjugated Polyelectrolyte/Graphene Multilayer Films for Simultaneous Electrochemical Sensing of Three Monohydroxylated Polycyclic

Aromatic Hydrocarbons. *ACS Applied Nano Materials, 2*(12), 7785-7794.

Panizza, M., Michaud, P., Cerisola, G., & Comninellis, C. (2001). Anodic oxidation of 2-naphthol at boron-doped diamond electrodes. *Journal of Electroanalytical Chemistry, 507*(1-2), 206-214.

Paputa-Peck, M., Marano, R., Schuetzle, D., Riley, T., Hampton, C., Prater, T., . . . Ruehle, P. (1983). Determination of nitrated polynuclear aromatic hydrocarbons in particulate extracts by using capillary column gas chromatography with nitrogen selective detection. *Analytical chemistry, 55*(12), 1946-1954.

Park, J., Lee, J. H., Jaworski, J., Shinkai, S., & Jung, J. H. (2014). Luminescent calix[4]arene-based metallogel formed at different solvent composition. *Inorganic chemistry, 53*(14), 7181-7187.

Partila, A. M., & Mohammed, M. R. (2019). Evaluation of the benzo [a] anthracene biodegradation by animal bioassays. *Bulletin of the National Research Centre, 43*(1), 1-7.

Patra, S., Maity, D., Gunupuru, R., Agnihotri, P., & Paul, P. (2012). Calixarenes: Versatile molecules as molecular sensors for ion recognition study. *Journal of Chemical Sciences, 124*(6), 1287-1299.

Pena, E. A., Ridley, L. M., Murphy, W. R., Sowa, J. R., & Bentivegna, C. S. (2015). Detection of polycyclic aromatic hydrocarbons (PAHs) in raw menhaden fish oil using fluorescence spectroscopy: Method development. *Environmental toxicology and chemistry, 34*(9), 1946-1958.

Polosa, R., Salvi, S., & Di Maria, G. U. (2002). Allergic susceptibility associated with diesel exhaust particle exposure: clear as mud. *Archives of Environmental Health: An International Journal, 57*(3), 188-193.

Pope III, C. A., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K., & Thurston, G. D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Jama, 287*(9), 1132-1141.

Pothuluri, J., Freeman, J., Evans, F., & Cerniglia, C. (1992). Fungal metabolism of acenaphthene by Cunninghamella elegans. *Applied and environmental microbiology, 58*(11), 3654-3659.

Preuss, R., Angerer, J., & Drexler, H. (2003). Naphthalene—an environmental and occupational toxicant. *International archives of occupational and environmental health, 76*(8), 556-576.

Primbs, T., Piekarz, A., Wilson, G., Schmedding, D., Higginbotham, C., Field, J., & Simonich, S. (2008). Influence of Asian and western US urban areas and fires on the atmospheric transport of PAHs, PCBs, and FTOHs in the western US. *Environmental science & technology, 42*(17), 6385.

Primbs, T., Simonich, S., Schmedding, D., Wilson, G., Jaffe, D., Takami, A., . . . Kajii, Y. (2007). Atmospheric outflow of anthropogenic semivolatile organic compounds from East Asia in spring 2004. *Environmental science & technology, 41*(10), 3551-3558.

Pulgarin, C., Adler, N., Peringer, P., & Comninellis, C. (1994). Electrochemical detoxification of a 1,4-benzoquinone solution in wastewater treatment. *Water Research, 28*(4), 887-893.

Qari, H. A., & Hassan, I. A. (2017). Bioaccumulation of PAHs in Padina boryana alga collected from a contaminated site on the Red Sea, Saudi Arabia. *Pol. J. Environ. Stud, 26*(1), 1.

Qiao, M., Wang, C., Huang, S., Wang, D., & Wang, Z. (2006). Composition, sources, and potential toxicological significance of PAHs in the surface sediments of the Meiliang Bay, Taihu Lake, China. *Environment International, 32*(1), 28-33.

Qiao, X., Wei, M., Tian, D., Xia, F., Chen, P., & Zhou, C. (2018). One-step electrosynthesis of cadmium/aluminum layered double hydroxides composite as electrochemical probe for voltammetric detection of anthracene. *Journal of Electroanalytical Chemistry, 808*, 35-40.

Qiu, Y.-W., Zhang, G., Liu, G.-Q., Guo, L.-L., Li, X.-D., & Wai, O. (2009). Polycyclic aromatic hydrocarbons (PAHs) in the water column and sediment core of Deep Bay, South China. *Estuarine, Coastal and Shelf Science, 83*(1), 60-66.

Rajasekhar, B., Nambi, I. M., & Govindarajan, S. K. (2020). Investigating the degradation of nC_{12} to nC_{23} alkanes and PAHs in petroleum-contaminated water by electrochemical advanced oxidation process using an inexpensive Ti/Sb-SnO_2/PbO_2 anode. *Chemical Engineering Journal*, 125268.

Rajeshwar, K., & Ibanez, J. G. (1997). *Environmental electrochemistry: Fundamentals and applications in pollution sensors and abatement*: Elsevier.

Ramos, K. S., & Moorthy, B. (2005). Bioactivation of polycyclic aromatic hydrocarbon carcinogens within the vascular wall: implications for human atherogenesis. *Drug metabolism reviews, 37*(4), 595-610.

Ravindra, K., Sokhi, R., & Van Grieken, R. (2008). Atmospheric polycyclic aromatic hydrocarbons: source attribution, emission factors and regulation. *Atmospheric Environment, 42*(13), 2895-2921.

Rehwagen, M., Müller, A., Massolo, L., Herbarth, O., & Ronco, A. (2005). Polycyclic aromatic hydrocarbons associated with particles in ambient air from urban and industrial areas. *Science of the Total Environment, 348*(1-3), 199-210.

Rhea, D. T., Gale, R. W., Orazio, C. E., Peterman, P. H., Harper, D. D., & Farag, A. M. (2005). Polycyclic aromatic hydrocarbons in water, sediment, and snow, from lakes in Grand Teton National Park, Wyoming. *US. Geological Survey, Columbia Environmental Research Center (USGS-CERC)*.

Robinson, R., & Stokes, R. (1955). Electrolyte solutions.(Appendix 12 I, p. 496.) Butterworths Scientific Publ. In: London.

Rybicki, B. A., Nock, N. L., Savera, A. T., Tang, D., & Rundle, A. (2006). Polycyclic aromatic hydrocarbon-DNA adduct formation in prostate carcinogenesis. *Cancer letters, 239*(2), 157-167.

Salinas-Torres, D., Huerta, F., Montilla, F., & Morallón, E. (2011). Study on electroactive and electrocatalytic surfaces of single walled carbon nanotube-modified electrodes. *Electrochimica Acta, 56*(5), 2464-2470.

Samat, N. (2010). Assessing land use land cover changes in Langkawi island: Towards sustainable urban living. *Malaysian Journal of Environmental Management, 11*(1), 48-57.

Santos, L. O., dos Anjos, J. P., Ferreira, S. L., & de Andrade, J. B. (2017). Simultaneous determination of PAHS, nitro-PAHS and quinones in surface and groundwater samples using SDME/GC-MS. *Microchemical Journal, 133*, 431-440.

Sany, S. B. T., Hashim, R., Salleh, A., Rezayi, M., Mehdinia, A., & Safari, O. (2014). Polycyclic aromatic hydrocarbons in coastal sediment of Klang Strait, Malaysia: distribution pattern, risk assessment and sources. *PloS one, 9*(4), e94907.

Sayin, S., Yilmaz, M., & Tavasli, M. (2011). Syntheses of two diamine substituted 1, 3-distal calix[4]arene-based magnetite nanoparticles for extraction of dichromate, arsenate and uranyl ions. *Tetrahedron, 67*(20), 3743-3753.

Schocken, M. J., & Gibson, D. T. (1984). Bacterial oxidation of the polycyclic aromatic hydrocarbons acenaphthene and acenaphthylene. *Applied and environmental microbiology, 48*(1), 10-16.

Scoggins, M., McClintock, N., Gosselink, L., & Bryer, P. (2007). Occurrence of polycyclic aromatic hydrocarbons below coal-tar-sealed parking lots and effects on stream benthic macroinvertebrate communities. *Journal of the North American Benthological Society, 26*(4), 694-707.

Sehatnia, B., Sabzi, R. E., Kheiri, F., & Nikoo, A. (2014). Sensitive molecular determination of polycyclic aromatic hydrocarbons based on thiolated Calix[4]arene and CdSe quantum dots (QDs). *Journal of Applied Electrochemistry, 44*(6), 727-733.

Senturk, Z. (2013). Analysis of carcinogenic polycyclic aromatic hydrocarbons (PAHs): an overview of modern electroanalytical techniques and their applications. *Current drug delivery, 10*(1), 76-91.

Serpe, F. P., Esposito, M., Gallo, P., & Serpe, L. (2010). Optimisation and validation of an HPLC method for determination of polycyclic aromatic hydrocarbons (PAHs) in mussels. *Food Chemistry, 122*(3), 920-925.

Settle, F. A. (1997). *Handbook of instrumental techniques for analytical chemistry*: Prentice Hall PTR.

Shao, Y., Wang, J., Engelhard, M., Wang, C., & Lin, Y. (2010). Facile and controllable electrochemical reduction of graphene oxide and its applications. *Journal of Materials Chemistry, 20*(4), 743-748.

Shen, X., Cui, Y., Pang, Y., & Qian, H. (2012). Graphene oxide nanoribbon and polyhedral oligomeric silsesquioxane assembled composite frameworks for pre-concentrating and electrochemical sensing of 1-hydroxypyrene. *Electrochimica Acta, 59*, 91-99.

Sing, K. S. (1985). Reporting physisorption data for gas/solid systems with special reference to the determination of surface area and porosity (Recommendations 1984). *Pure and applied chemistry, 57*(4), 603-619.

Singh, C., Sharma, V., Naik, P. K., Khandelwal, V., & Singh, H. (2011). A green biogenic approach for synthesis of gold and silver nanoparticles using Zingiber officinale.

Smith, R. E., Davies, T. J., Baynes, N. d. B., & Nichols, R. J. (2015). The electrochemical characterisation of graphite felts. *Journal of Electroanalytical Chemistry, 747*, 29-38.

Sun, J.-H., Wang, G.-L., Chai, Y., Zhang, G., Li, J., & Feng, J. (2009). Distribution of polycyclic aromatic hydrocarbons (PAHs) in Henan reach of the Yellow River, Middle China. *Ecotoxicology and environmental safety, 72*(5), 1614-1624.

Sun, L., Campbell, M. G., & Dincă, M. (2016). Electrically conductive porous metal–organic frameworks. *Angewandte Chemie International Edition, 55*(11), 3566-3579.

Sun, R., Sun, Y., Li, Q. X., Zheng, X., Luo, X., & Mai, B. (2018). Polycyclic aromatic hydrocarbons in sediments and marine organisms: Implications of anthropogenic effects on the coastal environment. *Science of the Total Environment, 640*, 264-272.

Supian, F. L., Choo, L., & Razali, A. S. (2017). Conductivity Comparison of Calix[8]arene-MWCNTs Through Spin Coating Technique. *Sains Malaysiana, 46*(1), 91-96.

Sverdrup, L. E., Nielsen, T., & Krogh, P. H. (2002). Soil ecotoxicity of polycyclic aromatic hydrocarbons in relation to soil sorption, lipophilicity, and water solubility. *Environmental science & technology, 36*(11), 2429-2435.

Tan, Y., Chen, L., Wu, F., Huang, B., Liao, Z., Yu, Z., . . . Chen, Y. (2018). Regulation of the Polar Groups in n-Type Conjugated Polyelectrolytes as Electron Transfer Layer for Inverted Polymer Solar Cells. *Macromolecules, 51*(20), 8197-8204.

Taşdemir, İ. H., Akay, M. A., Erk, N., & Kılıç, E. (2010). Voltammetric behavior of telmisartan and cathodic adsorptive stripping voltammetric method for its assay in pharmaceutical dosage forms and biological fluids. *Electroanalysis, 22*(17-18), 2101-2109.

Titato, G. M., & Lanças, F. M. (2006). Optimization and validation of HPLC-UV-DAD and HPLC-APCI-MS methodologies for the determination of selected PAHs in water samples. *Journal of chromatographic science, 44*(1), 35-40.

Toriba, A., Kuramae, Y., Chetiyanukornkul, T., Kizu, R., Makino, T., Nakazawa, H., & Hayakawa, K. (2003). Quantification of polycyclic aromatic hydrocarbons (PAHs) in human hair by HPLC with fluorescence detection: a biological monitoring method to evaluate the exposure to PAHs. *Biomedical Chromatography, 17*(2-3), 126-132.

Tovide, O., Jahed, N., Sunday, C. E., Pokpas, K., Ajayi, R. F., Makelane, H. R., . . . Iwuoha, E. I. (2014). Electro-oxidation of anthracene on polyanilino-graphene composite electrode. *Sensors and Actuators B: Chemical, 205*, 184-192.

Vallés, C., Jiménez, P., Munoz, E., Benito, A. M., & Maser, W. K. (2011). Simultaneous reduction of graphene oxide and polyaniline: doping-assisted formation of a solid-state charge-transfer complex. *The Journal of Physical Chemistry C, 115*(21), 10468-10474.

Venkatesan, M. (1988). Occurrence and possible sources of perylene in marine sediments-a review. *Marine Chemistry, 25*(1), 1-27.

Wang, C., Zhou, S., Wu, S., Song, J., Shi, Y., Li, B., & Chen, H. (2017). Surface water polycyclic aromatic hydrocarbons (PAH) in urban areas of Nanjing, China. *Water Science and Technology, 76*(8), 2150-2157.

Wang, D. (2016). In Calixarenes and Beyond; Neri, P., Sessler, J., Wang, M.-X., Eds. In: Springer International Publishing: Cham, Switzerland.

Wang, L.-R., Wang, Y., Chen, J.-W., & Guo, L.-H. (2009). A structure-based investigation on the binding interaction of hydroxylated polycyclic aromatic hydrocarbons with DNA. *Toxicology, 262*(3), 250-257.

Wang, X., Tao, S., Dawson, R., & Xu, F. (2002). Characterizing and comparing risks of polycyclic aromatic hydrocarbons in a Tianjin wastewater-irrigated area. *Environmental Research, 90*(3), 201-206.

Wang, Y., Wu, Y., Xie, J., & Hu, X. (2013). Metal–organic framework modified carbon paste electrode for lead sensor. *Sensors and Actuators B: Chemical, 177*, 1161-1166.

Wei, M., Duan, S., Liu, S., Zheng, X., Xia, F., & Zhou, C. (2015). Electrochemical determination of phenanthrene based on anthraquinone sulfonate and poly diallyldimethylammonium chloride modified indium–tin oxide electrode. *RSC advances, 5*(60), 48811-48815.

Wester, P., Muller, J., Slob, W., Mohn, G., Dortant, P., & Kroese, E. (2012). Carcinogenic activity of benzo [a] pyrene in a 2 year oral study in Wistar rats. *Food and chemical toxicology, 50*(3-4), 927-935.

WHO. (1993). *Guidelines for drinking-water quality*: World Health Organization.

Wilson, C. J., Clegg, R. E., Leavesley, D. I., & Pearcy, M. J. (2005). Mediation of biomaterial–cell interactions by adsorbed proteins: a review. *Tissue engineering, 11*(1-2), 1-18.

Wolkenstein, K. (2019). Characterization of polycyclic aromatic hydrocarbons and their phenanthroperylene quinone precursors in fossil crinoids using liquid chromatography–atmospheric pressure photoionization mass spectrometry. *Organic Geochemistry, 136*, 103892.

Wong, T.-H., Lee, C.-L., Su, H.-H., Lee, C.-L., Wu, C.-C., Wang, C.-C., . . . Lin, C.-C. (2018). A prominent air pollutant, Indeno [1, 2, 3-cd] pyrene, enhances allergic lung inflammation via aryl hydrocarbon receptor. *Scientific reports, 8*(1), 1-11.

Xie, W.-H., Shiu, W.-Y., & Mackay, D. (1997). A review of the effect of salts on the solubility of organic compounds in seawater. *Marine Environmental Research, 44*(4), 429-444.

Xiu, M., Pan, L., & Jin, Q. (2014). Bioaccumulation and oxidative damage in juvenile scallop Chlamys farreri exposed to benzo [a] pyrene, benzo [b] fluoranthene and chrysene. *Ecotoxicology and environmental safety, 107*, 103-110.

Xu, S., Liu, W., & Tao, S. (2006). Emission of polycyclic aromatic hydrocarbons in China. *Environmental science & technology, 40*(3), 702-708.

Yan, Y., Bo, X., & Guo, L. (2020). MOF-818 metal-organic framework-reduced graphene oxide/multiwalled carbon nanotubes composite for electrochemical sensitive detection of phenolic acids. *Talanta*, 121123.

Yang, D.-H., Lee, C.-S., Jeon, B.-H., Choi, S. M., Kim, Y.-D., Shin, J. S., & Kim, H. (2017). An electrochemical nanofilm sensor for determination of 1-hydroxypyrene using molecularly imprinted receptors. *Journal of Industrial and Engineering Chemistry, 51*, 106-112.

Yang, J., & Gunasekaran, S. (2013). Electrochemically reduced graphene oxide sheets for use in high performance supercapacitors. *Carbon, 51*, 36-44.

Yao, C., Chen, C., & Li, M. (2012). Analysis of rural residential energy consumption and corresponding carbon emissions in China. *Energy Policy, 41*, 445-450.

Yaqub, A., Isa, M., & Kutty, S. (2013). Electrochemical oxidation of PAHs in aqueous solution. In *Developments in sustainable chemical and bioprocess technology* (pp. 89-96): Springer.

Yaqub, A., Isa, M. H., Kutty, S. R. M., & Ajab, H. (2014). Electrochemical degradation of PAHs in produced water using Ti/Sb_2O_5-SnO_2-IrO_2 anode. *Electrochemistry, 82*(11), 979-984.

Yardım, Y., Keskin, E., Levent, A., Özsöz, M., & Şentürk, Z. (2010). Voltammetric studies on the potent carcinogen, 7, 12-dimethylbenz[a]anthracene: Adsorptive stripping voltammetric determination in bulk aqueous forms and human urine samples and detection of DNA interaction on pencil graphite electrode. *Talanta, 80*(3), 1347-1355.

Yardım, Y., Levent, A., Keskin, E., & Şentürk, Z. (2011). Voltammetric behavior of benzo[a]pyrene at boron-doped diamond electrode: A study of its determination by adsorptive transfer stripping voltammetry based on the enhancement effect of anionic surfactant, sodium dodecylsulfate. *Talanta, 85*(1), 441-448.

Ye, Q., Zhuang, H., & Zhou, C. (2009). Detection of naphthalene by real-time immuno-PCR using molecular beacon. *Molecular and cellular probes, 23*(1), 29-34.

Yomthiangthae, P., Kondo, T., Chailapakul, O., & Siangproh, W. (2020). The effects of the supporting electrolyte on the simultaneous determination of vitamin B_2, vitamin B_6, and vitamin C using a modification-free screen-printed carbon electrode. *New Journal of Chemistry, 44*(29), 12603-12612.

Yu, Z., Lin, Q., Gu, Y., Du, F., Wang, X., Shi, F., . . . Yu, Y. (2019). Bioaccumulation of polycyclic aromatic hydrocarbons (PAHs) in wild marine fish from the coastal waters of the northern South China Sea:

Risk assessment for human health. *Ecotoxicology and environmental safety, 180*, 742-748.

Yuan, X., & Oleschuk, R. D. (2018). Advances in microchip liquid chromatography. *Analytical chemistry, 90*(1), 283-301.

Zainal, P. N. S., Ahmad, S. A. A., & Ngee, L. H. (2019). Surface Modification of Screen-Printed Carbon Electrode (SPCE) with Calixarene-Functionalized Electrochemically Reduced Graphene Oxide (ERGO/C4) in the Electrochemical Detection of Anthracene. *Journal of The Electrochemical Society, 166*(2), B110-B116.

Zainal, P. N. S., Ahmad, S. A. A., & Ngee, L. H. (2019). Surface Modification of Screen-Printed Carbon Electrode (SPCE) with Calixarene-Functionalized Electrochemically Reduced Graphene Oxide (ERGO/C4) in the Electrochemical Detection of Anthracene. *Journal of The Electrochemical Society, 166*(2), B110.

Zainal, P. N. S., Ahmad, S. A. A., Ngee, L. H., & Ling, I. (2020). Development of electrochemical sensor based on thiolated calixarene-functionalized gold nanoparticles for the selective recognition of anthracene. *IEEE Sensors Journal*.

Zakaria, M. P., Okuda, T., & Takada, H. (2001). Polycyclic aromatic hydrocarbon (PAHs) and hopanes in stranded tar-balls on the coasts of Peninsular Malaysia: applications of biomarkers for identifying sources of oil pollution. *Marine Pollution Bulletin, 42*(12), 1357-1366.

Zeng, E. Y., & Vista, C. L. (1997). Organic pollutants in the coastal environment off San Diego, California. 1. Source identification and assessment by compositional indices of polycyclic aromatic hydrocarbons. *Environmental Toxicology and Chemistry: An International Journal, 16*(2), 179-188.

Zhang, C., Wang, M., Liu, L., Yang, X., & Xu, X. (2013). Electrochemical investigation of a new Cu-MOF and its electrocatalytic activity towards H_2O_2 oxidation in alkaline solution. *Electrochemistry Communications, 33*, 131-134.

Zhang, H., Xue, M., & Dai, Z. (2010). Determination of polycyclic aromatic hydrocarbons in aquatic products by HPLC-fluorescence. *Journal of Food Composition and Analysis, 23*(5), 469-474.

Zhang, M., Zhang, X., Shi, Y.-e., Liu, Z., & Zhan, J. (2016). Surface enhanced Raman spectroscopy hyphenated with surface microextraction for in-situ detection of polycyclic aromatic hydrocarbons on food contact materials. *Talanta, 158*, 322-329.

Zhang, X., Li, L., Li, L., Chen, J., Zou, G., Si, Z., & Jin, W. (2009). Ultrasensitive electrochemical DNA assay based on counting of single magnetic nanobeads by a combination of DNA amplification and enzyme amplification. *Analytical chemistry, 81*(5), 1826-1832.

Zhang, Y., Bo, X., Luhana, C., Wang, H., Li, M., & Guo, L. (2013). Facile synthesis of a Cu-based MOF confined in macroporous carbon hybrid material with enhanced electrocatalytic ability. *Chemical Communications, 49*(61), 6885-6887.

Zhang, Y., Dian, P. G., & Zhuang, H. S. (2011). *Detection of Anthracene in Real Water Samples with A Label-free Amperometric Immunosenor.* Paper presented at the Advanced Materials Research.

Zhang, Y., Dou, H., Chang, B., Wei, Z., Qiu, W., Liu, S., . . . Tao, S. (2008). Emission of polycyclic aromatic hydrocarbons from indoor straw burning and emission inventory updating in China. *Annals of the New York Academy of Sciences, 1140*(1), 218-227.

Zhang, Y., & Tao, S. (2009). Global atmospheric emission inventory of polycyclic aromatic hydrocarbons (PAHs) for 2004. *Atmospheric Environment, 43*(4), 812-819.

Zhang, Y., Tao, S., Cao, J., & Coveney, R. M. (2007). Emission of polycyclic aromatic hydrocarbons in China by county. *Environmental science & technology, 41*(3), 683-687.

Zhao, X., Qiu, H., Zhao, Y., Shen, J., Chen, Z., & Chen, J. (2015). Distribution of polycyclic aromatic hydrocarbons in surface water from the upper reach of the Yellow River, Northwestern China. *Environmental Science and Pollution Research, 22*(9), 6950-6956.

Zheng, X., Tian, D., Duan, S., Wei, M., Liu, S., Zhou, C., . . . Wu, G. (2014). Polypyrrole composite film for highly sensitive and selective electrochemical determination sensors. *Electrochimica Acta, 130*, 187-193.

Zhu, C., Yang, G., Li, H., Du, D., & Lin, Y. (2014). Electrochemical sensors and biosensors based on nanomaterials and nanostructures. *Analytical chemistry, 87*(1), 230-249.

Zhu, L., Chen, B., Wang, J., & Shen, H. (2004). Pollution survey of polycyclic aromatic hydrocarbons in surface water of Hangzhou, China. *Chemosphere, 56*(11), 1085-1095.

Zhu, L., Luo, L., & Wang, Z. (2012). DNA electrochemical biosensor based on thionine-graphene nanocomposite. *Biosensors and Bioelectronics, 35*(1), 507-511.

Zhuang, H.-S., & Zhou, C. (2009). Determination of anthracene by real-time immuno-polymerase chain reaction assay. *Analytica chimica acta, 633*(2), 278-282.

Zhuiykov, S., & Kalantar-zadeh, K. (2012). Development of antifouling of electrochemical solid-state dissolved oxygen sensors based on nanostructured $Cu_{0.4}Ru_{3.4}O_7$ + RuO_2 sensing electrodes. *Electrochimica Acta, 73*, 105-111.