PREPARATION OF ACTIVATED CARBON NANOMATERIAL FROM PALM OIL KERNEL SHELL FOR REMOVAL OF HEAVY METAL IONS

By

BABY RABIA

Thesis submitted to the School of Graduate Studies Universiti Putra Malaysia, in the Fulfilment of the Requirements for the Degree of Doctor of Philosophy

September 2022

ITMA 2022 15

COPYRIGHT

DEDICATION

I dedicated my thesis to my father Late. Dr. Capt. Mohammad Iqbal Shaikh, my dearest mother Mrs. Shahmeer Shaikh, who always encouraged me for higher studies, my kids and loving Husband Dr. Saifullah Bullo who was always beside me with his full support.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

PREPARATION OF ACTIVATED CARBON NANOMATERIAL FROM PALM OIL KERNEL SHELL FOR REMOVAL OF HEAVY METAL IONS

By

BABY RABIA

September 2022

Chairman : Professor Mohd Zobir bin Hussein, PhD
Institute : Nanoscience and Nanotechnology

Environmental pollution is greatly caused by industrialization as well as human beings and water contamination is one of the major hazards for living. Many kinds of contaminants have been studied such as bacteria, viruses, organic molecules, dyes and heavy metal ions, such as Cr^{6+}, Pb^{2+}, Cd^{2+}, Zn^{2+}, As^{3+}, $Cu^{2+}$and $Hg^{2+,}$ etc. Among all these contaminants, heavy metal ions are non-biodegradable in nature and can accumulate in the human body continuously over time, which results in severe adverse effects like a breakdown of the nervous system, skin diseases, liver damage, kidney failure, anemia, hepatitis, ulcers and carcinogenic. The key objectives of this study are to prepare the PKS powder, the functionalization of the PKS powder, preparation of activated carbon nanomaterial (ACN) and functionalized ACN and application for the treatment of heavy metal-contaminated water. In this study, four heavy metal ions namely chromium (Cr^{6+}), lead (Pb^{2+}), cadmium (Cd^{2+}) and zinc (Zn^{2+}) were selected as the water contaminants. Furthermore, four different bio-sorbents were prepared namely PKS powder, functionalized PKS (PKS-Sulfo), activated carbon (AC) and functionalized activated carbon (FAC). All of these adsorbents were successfully applied for the treatment of heavy metal-contaminated water. They showed good adsorption affinities for the Cr^{6+}, Pb^{2+}, Cd^{2+} and Zn^{2+} heavy metal ions. Adsorption of Cr^{6+} and Pb^{2+} was determined to be maximum almost reach to 99% in case of each adsorbent. The Cd^{2+} whose adsorption was found to be 80-85% , followed by 70-75% of Zn^{2+} ions adsorption in all four applied adsorbents.Two isotherm models namely Freundlich and Langmuir and three kinetics models namely the pseudo-first-order, pseudo-second-order and Parabolic diffusion were applied for the determinations of kinetic interactions between the adsorbents; (PKS, PKS-Sulfo, AC and FAC) and the adsorbates; (Cr^{6+}, Pb^{2+}, Cd^{2+} and Zn^{2+}). The adsorption followed Pseudo Second Order in all cases of the adsorbents. Langmuir adsorption isotherm was found to be followed in case of PKS-Sulfo, and only zinc adsorption in PKS,apart from this Aacivated carbon (AC, Functionalzied Activated Carbon (FAC) as well as PKS were found to follow Freundlich isotherm model. PKS-Sulfo The adsorption efficiency among all four adsorbents was found to be in the order of FAC> AC>PKS-Sulfo>PKS. This is a greener approach that can serve the dual

function of the protection environment from smoke resulting from the burning of PKS waste. The first function was by converting the PKS into a useful material instead of burning it and secondly it is applied for the treatment of heavy metal-contaminated water. The designed materials can further be exploited for dye-contaminated water, the chemical industry, the food industry, catalysis, air and gas purifications and automobile industries, etc.

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

PENYEDIAAN BAHAN NANO KARBON AKTIF DARIPADA TEMPURUNG ISIRONG SAWIT UNTUK PENYINGKIRAN ION LOGAM BERAT

Oleh

BABY RABIA

September 2022

Pengerusi : Profesor Mohd Zobir bin Hussein, PhD
Institut : Nanosains dan Nanotechnologi

Pencemaran alam sekitar banyak disebabkan oleh perindustrian dan juga manusia dan pencemaran air adalah salah satu bahaya utama untuk kehidupan. Banyak jenis bahan cemar telah dikaji seperti bakteria, virus, molekul organik, pewarna dan ion logam berat seperti Cr^{6+}, Pb^{2+}, Cd^{2+}, Zn^{2+}, As^{3+}, Cu^{2+} dan Hg^{2+}, dsb. Di antara semua ini, ion logam berat tidak boleh terbiodegradasi dan boleh terkumpul dalam tubuh manusia secara berterusan mengikut masa, yang mengakibatkan kesan buruk yang teruk seperti kerosakan sistem saraf, penyakit kulit, kerosakan hati, kegagalan buah pinggang, anemia, hepatitis, ulser dan kesan karsinogenik. Dalam kajian ini empat ion logam berat iaitu kromium (Cr^{6+}), plumbum (Pb^{2+}), kadmium (Cd^{2+}) dan zink (Zn^{2+}) yang merupakan bahan cemar air telah dipilih. Tempurung isirong sawit (PKS) telah dihaluskan menjadi serbuk dengan menggunakan pengisar elektrik dan seterusnya dirawat dengan kepekatan asid sulfurik yang berbeza untuk menghasilkan kumpulan berfungsi. PKS juga telah dirawat dengan asid fosforik untuk sintesis karbon teraktif diikuti dengan pengoptimuman masa dan suhu di dalam relau tiub elektrik dengan aliran gas nitrogen yang berterusan pada kadar alir 150 cm^3/minit. Karbon teraktif juga telah difungsikan lagi dengan menggunakan asid nitrik pada kepekatan berbeza yang menghasilkan karbon teraktif terfungsi (FAC). Kajian kelompok telah dijalankan untuk rawatan air tercemar logam berat dan parameter yang berbeza seperti pH larutan, dos penjerap, masa sentuhan, dan kepekatan ion logam telah dioptimumkan untuk setiap penjerap. Mereka menunjukkan pertalian penjerapan yang baik untuk ion logam berat Cr6+, Pb^{2+} , Cd^{2+} dan Zn^{2+}. Penjerapan Cr^{6+} dan Pb^{2+} ditentukan untuk maksimum hampir mencapai 99% dalam kes setiap penjerap. Cd^{2+} yang penjerapannya didapati 80-85%, diikuti oleh 70-75% penjerapan ion Zn^{2+} dalam keempat-empat penjerap yang digunakan. Dua model isoterma iaitu Freundlich dan Langmuir dan tiga model kinetik iaitu pseudo-first-order, pseudo- resapan tertib kedua dan Parabolik digunakan untuk penentuan interaksi kinetik antara penjerap; (PKS, PKS-Sulfo, AC dan FAC) dan bahan penjerap; (Cr^{6+},Pb^{2+}, Cd^{2+} dan Zn^{2+}). Penjerapan mengikut Pseudo Second Order dalam semua kes penjerap. Isoterma penjerapan Langmuir didapati diikuti dalam kes PKS-Sulfo, dan hanya penjerapan zink dalam PKS, selain daripada karbon Aacivated (AC, Karbon Aktif

Berfungsi (FAC) serta PKS didapati mengikuti model isoterma Freundlich.Kecekapan penjerapan di antara keempat-empat penjerap adalah mengikut urutan FAC>AC>PKS-Sulfo>PKS. Kaedah ini merupakan pendekatan yang lebih hijau yang dengan dwifungsi untuk perlindungan persekitaran daripada asap akibat pembakaran sisa PKS. Fungsi pertama ialah menukar PKS menjadi bahan berguna dan bukannya membakarnya dan kedua ia digunakan untuk rawatan air tercemar logam berat. Bahan-bahan yang direka bentuk boleh terus dieksploitasi untuk rawatan air tercemar pewarna, industri kimia, industri makanan, pemangkinan, penulenan udara dan gas dan industri automobil.

ACKNOWLEDGEMENTS

All praise to Almighty Allah, who has given me the courage to finish my thesis work and fulfill my dreams. My special gratitude goes to my dear mother and elder sister for their continuous support. Special thanks to my lovely husband who always cares about my emotions and helps and suggests me meaningful ideas to fill gaps in my research areas. I am grateful to my kind and devoted supervisor; Prof. Dr. Mohd Zobir bin Hussein, who was incredibly efficient with vast knowledge in guidance and for the never-ending support and kindness. I would also like to thank my co-supervisors; Prof. Dr. Abdul Halim Abdullah and Prof. Dr. Zulkarnain Zainal for their support and assistance. I am truly thankful to all my friends of UPM, ION2, NAMASTE group as they turned this challenging journey of seeking knowledge and self-discovery into a more pleasant experience, the cooperation is indeed very much appreciated. My profound gratitude to the staff at the Institute of Nanoscience & Nanotechnology (ION2) UPM who has also been very helpful and kind to me throughout my research journey. Last but not least I am really grateful to Sukkur IBA University (SIBAU), my colleagues and special gratitude to the founder of SIBAU Late Prof. Nisar Ahmed Siddiqui who has inspired the generations toward higher education and research.

This thesis was submitted to the Senate of the 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:

Mohd Zobir bin Hussein, PhD
Professor
Institute of Nanoscience and Nanotechnology
Universiti Putra Malaysia
(Chairman)

Zulkarnain bin Zainal, PhD
Professor ChM.
Faculty of Science
Universiti Putra Malaysia
(Member)

Halim bin Abdullah, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 9 March 2023

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: Professor Dr. Mohd Zobir bin Hussein

Signature: _____
Name of Member of Supervisory Committee: Professor ChM. Dr. Zulkarnain bin Zainal

Sig:nature _____
Name of Member of Supervisory Committee: Associate Professor Dr. Halim bin Abdullah

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Full-Form
PKS	Palm Kernel Shell
PKS-Sulfo	Palm Kernel Shell-Sulfonated
AC	Activated Carbon
FAC	Functionalized Activated Carbon
XRD	X-Ray Diffraction
FTIR	Fourier Transformed Infrared
BET	Brunauer-Emmett-Teller
FESEM	Field Emission Scanning Electron Microscopy

CHAPTER 1

INTRODUCTION

1.1 Background of Studies

Pollution is termed as the presence of undesirable chemical entity/entities preventing the natural process or causing adverse effects on living organisms and the environment (Ayawei Nimibofa, 2018; Poorva Mehndiratta, 2013; Wu et al., 2019). Industrialization and the immense increase in population led to growing urbanization causing an increase in pollution at an alarming rate (Poorva Mehndiratta, 2013; X. Zhang et al., 2017). Improving the water, soil and air quality is an immense challenge of the modern era. Identification and treatment of environmental pollutants and their prevention is a key step in the protection of the environment. Pure and clean water is getting scarce due to industrialization, and the world is facing a shortage of clean water, especially in developing countries (World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2017). Water contaminants can be organics, bacteria, viruses, dyes, and heavy metal ions such as lead, cadmium, zinc, nickel, arsenic, chromium and mercury with non-biodegradable nature posing a great risk to human health. Heavy metal ions can cause many adverse affects like cancer, kidney damage, hepatitis, miscarriages, anemia, encephalopathy and nephritic syndrome, etc. (Sardans et al. 2011; Tlili, 2018; Yang et al. 2018). Lead ions are released in the environment generally from metal mining industries of acid lead batteries, paper, glass and polishing industries. Cadmium is generally found in water discharged from the electroplating designing of batteries, photovoltaic cells, metallurgy processes, and fabric factories (Xiangtao Wang, 2012). Nickel ions can cause skin diseases when contacted with jewelry trashing, zips, watches, and coins, etc. Cr(VI) ions cause diseases like liver damage, nephritis, stomach distresses and a nasal mucous ulcer (Moreno-Castilla et al. 2004). Because of these severe adverse effects, the removal of heavy metal ions from water is of prime importance for saving human lives from such problematic health issues. Toxic metal ions could be removed by numerous methods, like ion exchange, reverse osmosis, precipitation filtration, biosorption, coagulation, and extraction, etc. (Fu & Wang, 2011; Huang et al., 2018). Adsorption is considered the best method as it is cost-effective, highly efficient, and easy to operate for removing trace levels of heavy metal ions (Czikkely 2018).

Nanotechnology plays a vital role in realizing the clean environmental goal and has progressed exponentially in the last decade (Culetu et al., 2014; Wu et al., 2019). Nanotechnology platform finds application almost in every field such as environmental science, health sciences, electronics, industrial separation, portable water treatment large/small scale plants, catalysts, energy storage, and energy generation, etc. (Liu et al., 2018; G. Zeng et al., 2018; G. Zeng et al., 2016). Nanomaterials provide a special platform for the purification of contaminated water due to their high surface area, their capability of chemical modification and easier regeneration. Nanomaterials are being exploited more and more for the removal of different types of pollutants namely organic, metal ions, biological contaminants, and arsenic, etc. from the water (Al-Senani & Al-Fawzan, 2018; Bozbaş & Boz, 2016; Bradder et al.2011; Brunet et al. 2009). Carbon

nanomaterials namely graphene, graphene oxide, carbon nanotubes, fullerenes, and activated carbons, etc. have been widely used in energy storage, sensor, electronics, water purification, drug delivery, and disease diagnosis, etc. owing to their exceptional chemical, mechanical, thermal and electrical characteristics. In this study (PKS)has been selected for the preparation of adsorbent materials namely PKS powder, functionalized PKS, activated carbon (AC) and functionalized activated carbon (FAC). Functionalization will confer on the more chemically active sites on the above material will enhance the adsorption efficiency of the functionalized material. And these adsorbent materials were successfully used for the treatment of heavy metal-contaminated water. Their kinetics as well as their isotherms studies were out in detail. The mechanisms of interactions of heavy metal ions with all these foru-designed adsorbents (PKS, PKS-Sulfo, Activated carbon and Functionalised activated carbon) were determined. All of these four adsorbents had a lot of active sites for the interactions with heavy metal ions and therefore were found to be efficient in removing the heavy metal-contaminated water.

1.2 Problem Statement

Clean water is getting scarce because of industrialization, and the world is confronting a deficiency of clean water. Among the different water contaminants, heavy metals are non-biodegradable and they get accumulated in the body over time and result in severe illness and disorders in humans as well as in other living creatures. Consumption of heavy metal-contaminated water or food can cause numerous health problems like a malignant growth, kidney damage, hepatitis, unsuccessful labor, iron deficiency, encephalopathy, nephritic disorder, and so forth (Anubhav et al., 2022; Rehman et al. 2018). Chromium metal (Cr^{6+}) can cause maladies like liver harm, nephritis, stomach problems and nasal mucous ulcers (Jacobs 2005). The concentration of Cr^{6+} in groundwater and surface water is exceeding World Health Organization (WHO) set limit of 50 µg per liter (Velma , 2009). Lead (Pb^{2+}) is a carcinogenic element declared by the Environmental Protection Agency (EPA). Lead poising is the term used for its toxicity and it may be acute or chronic. Lead poisoning can cause mental retardation, birth defects autism, allergies, dyslexia, paralysis, brain damage, kidney damage and may also result in death etc. (Martin, 2009). Cadmium-induced toxicity to kidneys, respiratory systems, and skeleton and is a carcinogen to humans (Monisha Jaishankar, 2014; Waalkes M, 2001). Cadmium is ranked 7th most toxic metal by the Agency for Toxic Substances and Disease Registry (ATSDR) (Jaishankar et al. 2014). Although zinc is essential to trace metals for humans, excessive absorption of zinc can suppress iron absorption. Zinc ions are highly toxic to plants, vertebrates, fishes and invertebrates, etc. (Brita, 2006; Fosmire et al., 2003).

Agricultural waste of oil palm is produced in millions of tons from Malaysia, Indonesia, Cameron, Africa, China and Nigeria (Nicholas et al. 2018). Malaysia is among the biggest producer and suppliers of oil palm with about 4.5 million hectares of cultivation and produces about $90x10^6$ tons of agricultural waste oil palm (PKS) is a sustainable source and usually, it is burned to dispose of causing the greenhouse effect and resulting in a negative impact the environment (Nicholas et al., 2018).

Different methods are widely applied for the removal of heavy metal ions from the aqueous solutions namely reverse osmosis, evaporation, colorimetric, ion exchange, precipitation, membrane and coagulation (Bradder et al., 2011; Cimxe, 2019; Hung et al., 2014; Wu et al., 2019). Because of the high cost, energy consumption and low concentration of metal ions are problems in the above techniques.

1.3 Objectives of the Study

The following are the key objectives of this research study.

A). To prepare the four different adsorbents Palm Kernel Shell (PKS) Powder, Functionalized PKS powder, Activated Carbon from PKS and Functionalized activatedcCarbon using physical blending, chemical method of oxidation, carbon vapour deposition method followed by chemical oxidationrespectively.

B). To optimize the preparation parameters of the above four adsorbents to get the best samples and their detailed characterization.

C). To perform adsorption study for the removal of heavy metal ions namely Cr^{6+}, Pb^{2+}, Cd^{2+}, and Zn^{2+} from the water using the prepared adsorbents.

D) To optimize the adsorption parameters; the pH of the solution, concentration of metal ions, contact time and the adsorbent dosages.

E). To analyze the kinetics studies using the models of pseudo-first-order, pseudo-second-order and parabolic-diffusion-order and isotherm models namely Freundlich and Langmuir, to study the kinetics and mechanism of interactions between metal ions and adsorbents.

1.4 Significant of studies

In this study, agricultural waste of Palm Kernel Shell (PKS) which is produced in millions of tons every year as an agricultural waste of oil palm upstream industries is produced in Malaysia, Indonesia, Cameron, Africa, China and Nigeria. Malaysia is among the biggest producer and suppliers of oil palm with about 4.5 million hectares of cultivation and produces about $90x10^6$ tons of agricultural waste oil palm. Most commonly the waste is disposed of by burning, causing a lot of smoke and haze resulting in a negative impact on the environment. The haze and smoke from the burning of the oil palm waste result in different eye diseases, skin diseases, and causing lung diseases.

On other hand, heavy metals are non-biodegradable environmental contaminants coming into the environment and water from industrial waste. Consumption of these heavy metals by living creatures from water heavy metals are also the main pollutants in groundwater.

In this study, agricultural waste of oil palm PKS was utilized for the preparation of the different adsorbents namely PKS Powder, Sulfonated PKS powder, Activated carbon (AC), and Functionalized activated carbon (FAC). The designed Adsorbents were successfully applied for the treatment of heavy metal-contaminated water through the adsorption process. The adsorption process is economical, more effective and user-friendly (easy to use) compared to the other water treatment methods such as reverse osmosis, evaporation, colorimetric, ion exchange, precipitation, membrane and coagulation. The designed materials have the potential to be applied for the treatment of other water pollutants such as dyes and bacteria, etc. This study is a greener approach for the conversion of agricultural waste into useful advanced material and it will serve dual purposes; protecting the environment from the smoke resulting from the burning of PKS and treatment of heavy metal-contaminated water. This study opens up new horizons for greener nanotechnology where other agricultural waste can also be converted into useful materials.

1.5 Scope of the Study

The focus of this study is to use the waste from the oil palm upstream industry for environmental remediation, firstly by converting the agricultural waste into useful advanced material. Agricultural waste from oil palm plantations is produced in millions of tons every year which can serve as a sustainable material. Most of them are dumbed by burning them off causing haze, and environmental pollution and resulting in health issues for living beings.

In this study, the shell (PKS) of the oil palm was grounded into fine powder for adsorption of heavy metal ions and selected to convert it into useful advanced material namely activated carbon using the technique of carbon vaporized depositor (CVD) and was further functionalized with nitric acid and sulfuric acid resulting in the functionalized activated carbon. Different parameters of activated carbon synthesis concentration of activating agent (phosphoric acid), temperature and holding time were optimized. These parameters were optimized to get the activated carbon with a high specific surface area. The best sample, i.e. the sample with the highest surface area was selected for further functionalized with nitric acid and sulfuric acid to get the nitro- and sulfo- functionalized activated carbon. In addition, the PKS was also directly functionalized with sulfuric acid, which resulted in PKS-Sulfo. This is a green approach for environmental remediations where agricultural waste has been converted to useful materials, namely PKS powder, PKS-Sulfo, activated carbon and functionalized activated carbons; instead of burning them off, this approach immensely contribute to avoiding air pollution. Furthermore, the designed useful materials have been applied for the treatment of heavy metal-contaminated water. The different parameters of the adsorption study; pH of the solution, contact time, adsorbent dosage and heavy metal ions solutions were varied to get the optimized condition for the maximum removal of heavy metal ions. This research serves dual purposes; first converting agricultural waste into useful and advanced materials and secondly, it also offers a solution for the treatment of heavy metal-contaminated water. Generally, this work only covers the use of PKS for the preparation of activated carbon and its functionalized products and their treatments for the removal of heavy metal ions from water.

The novelty of this study is that a waste material of agriculture produced in millions of od tons every year causing a lot of environmental pollution due to burning off for its disposal; has been converted into four different advanced useful materials. Not only this, but this material is also further utilized for environmental remediation for the removal of heavy metal ions from water. Therefore, this study serves a dual purpose conversion of waste material to use advanced materials and applying them for further protection of the environment.

The limitations of this study are, the designed materials can be applied for the removal of the dyes from water. Furthermore, these can also be used as a stationary phase of the glass columns for the removal of contaminants from water both dyes as well heavy metal ions. Recycling of adsorbents can also be done and reuse of the material for further experiments can be done which was not done due to limit access to laboratories due to covid-19 MCO. we have not conducted the antimicrobial and antifungal studies of design materials but we do expect these activities from prepared material.

REFERENCES

Al-Senani, G. M., & Al-Fawzan, F. F. (2018). Adsorption study of heavy metal ions from aqueous solution by nanoparticle of wild herbs. *The Egyptian Journal of Aquatic Research, 44*(3), 187-194.

Ayawei Nimibofa, E. A. N., Abasi Yameso Cyprain & Wankasi Donbebe. (2018). Fullerenes: Synthesis and Applications. *Jurnal of Materials Science Research, 7*(3), 16.

Abeer El-Saharty, S. N. M., Ahmed Hashem Manjood, Adel Abdel Hady Nassar, Abdel Moneum Ahmed. (2018). Effect of Apricot Stone Activated Carbon Adsorbent on the Removal of Toxic Heavy Metals Ions from Aqueous Solutions. *International Journal of Ecotoxicology and Ecobiology, 3*(2), 13.

Acharya, J., Sahu, J., Mohanty, C., Meikap, B. (2009). Removal of lead (II) from wastewater by activated carbon developed from tamarind wood by zinc chloride activation. *Chem. Eng. J., 149* (1), 14.

Ahmed A. Moosa, A. M. R., Ibtihal Najem Abdullha. (2015). Chromium Ions Removal from Wastewater Using Carbon Nanotubes. *International Journal of Innovative Research in Science,Engineering and Technology, 4*(2), 8.

Ahmadi, V. E., Khaksaran, M. H., Apak, A. M., Apak, A., Parlak, M., Tastan, U.Koşar, A. (2022). Graphene-coated sintered porous copper surfaces for boiling heat transfer enhancement. *Carbon Trends, 8*, 100171.

Aïssa, B., Memon, N. K., Ali, A., & Khraisheh, M. K. (2015). Recent Progress in the Growth and Applications of Graphene as a Smart Material: A Review. *Frontiers in Materials, 2*(58).

Al-Senani, G. M., & Al-Fawzan, F. F. (2018). Adsorption study of heavy metal ions from aqueous solution by nanoparticle of wild herbs. *The Egyptian Journal of Aquatic Research, 44*(3), 187-194.

Alekseeva, O. V., Bagrovskaya, N. A., & Noskov, A. V. (2016). Sorption of heavy metal ions by fullerene and polystyrene/fullerene film compositions. *Protection of Metals and Physical Chemistry of Surfaces, 52*(3), 443-447.

Ali, I., Basheer, A. A., Mbianda, X. Y., Burakov, A., Galunin, E., Burakova, I., Grachev, V. (2019). Graphene based adsorbents for remediation of noxious pollutants from wastewater. *Environment International, 127*, 160-180.

Ali, S., Rehman, S. A. U., Luan, H.-Y., Farid, M. U., & Huang, H. (2019). Challenges and opportunities in functional carbon nanotubes for membrane-based water treatment and desalination. *Science of The Total Environment, 646*, 1126-1139.

Alijani, H., & Shariatinia, Z. (2018). Synthesis of high growth rate SWCNTs and their magnetite cobalt sulfide nanohybrid as super-adsorbent for mercury removal. *Chemical Engineering Research and Design, 129*, 132-149.

Alina, M., Azrina, A., Mohd Yunus, A.S., Mohd Zakiuddin, S., Mohd Izuan Effendi, H. and Muhammad Rizal, R. (2012). Heavy metals (Mercury, Arsenic, Cadmium, Plumbum) in selected marine fish and shellfish along the Straits of Malacca. *International Food Research Journal 19*(1), 6.

Ahmed A. Moosa, A. M. R., Ibtihal Najem Abdullha. (2015). Chromium Ions Removal from Wastewater Using Carbon Nanotubes. *International Journal of Innovative Research in Science,Engineering and Technology, 4*(2), 8.

Ahmed M, M. M., Ozaki A, Thinh NV, Kurosawa K. . (2019). Heavy Metal Contamination of Irrigation Water, Soil, and Vegetables and the Difference between Dry and Wet Seasons Near a Multi-Industry Zone in Bangladesh. *Water, 11*(3).

Ahmed, M. J. (2016). Application of agricultural based activated carbons by microwave and conventional activations for basic dye adsorption: . *Journal of environmental chemical Engineering, 4* (1), 10.

Ammari, A., & Schroen, K. (2018). Flavor Retention and Release from Beverages: A Kinetic and Thermodynamic Perspective. *Journal of Agricultural and Food Chemistry, 66*(38), 9869-9881.

Ayawei, N., Ebelegi, A. N., & Wankasi, D.(2017) - Modelling and Interpretation of Adsorption Isotherms.

Ahmed, M. J. (2016). Application of agricultural based activated carbons by microwave and conventional activations for basic dye adsorption: . *Journal of environmental chemical Engineering, 4* (1), 10.

Al-Ghouti, M. A., & Al-Absi, R. S. (2020). Mechanistic understanding of the adsorption and thermodynamic aspects of cationic methylene blue dye onto cellulosic olive stones biomass from wastewater. *Scientific Reports, 10*(1), 15928.

Ali, H., Khan, E., & Ilahi, I. (2019). Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. *Journal of Chemistry, 2019*, 6730305.

Alina M, A. A., Mohd Yunus AS, Mohd Zakiuddin S, Mohd Izuan Eff endi, & H, M. R. R. (2012). Heavy metals (mercury, arsenic, cadmium, plumbum) in selected marine fi sh and shellfi sh along the Straits of Malacca.. *Int Food Res J, 19*(1), 5.

Al-Senani, G. M., & Al-Fawzan, F. F. (2018). Adsorption study of heavy metal ions from aqueous solution by nanoparticle of wild herbs. *The Egyptian Journal of Aquatic Research, 44*(3), 187-194.

Alshehri, R., Ilyas, A. M., Hasan, A., Arnaout, A., Ahmed, F., & Memic, A. (2016). Carbon Nanotubes in Biomedical Applications: Factors, Mechanisms, and Remedies of Toxicity. *Journal of Medicinal Chemistry, 59*(18), 8149-8167.

Alslaibi, T. M., Abustan, I., Ahmad, M., Abu Foul, A., . (2013). Application of response surface methodology (RSM) for optimization of Cu2+, Cd2+, Ni2+, Pb2+, Fe2+, and Zn2+ removal from aqueous solution using microwaved olive stone activated carbon. *J. Chem. Technol. Biotechnol., 88*(12), 11.

Ammari, A., & Schroen, K. (2018). Flavor Retention and Release from Beverages: A Kinetic and Thermodynamic Perspective. *Journal of Agricultural and Food Chemistry, 66*(38), 9869-9881.

Ambroz, F., Macdonald, T. J., Martis, V., & Parkin, I. P. (2018). Evaluation of the BET Theory for the Characterization of Meso and Microporous MOFs. *Small Methods, 2*(11), 1800173.

Anah, L., & Astrini, N. (2018). Isotherm adsorption studies of Ni(II) ion removal from aqueous solutions by modified carboxymethyl cellulose hydrogel. *IOP Conference Series: Earth and Environmental Science, 160*(1), 012017.

Andrews, R., Jacques, D., Qian, D., & Rantell, T. (2002). Multiwall Carbon Nanotubes: Synthesis and Application. *Accounts of Chemical Research, 35*(12), 1008-1017.

Anitha, K., Namsani, S., & Singh, J. K. (2015). Removal of Heavy Metal Ions Using a Functionalized Single-Walled Carbon Nanotube: A Molecular Dynamics Study. *The Journal of Physical Chemistry A, 119*(30), 8349-8358.

Anubhav, S., Anuj, S., Rohit, K. V., Rushikesh, L. C., Pritam, P. P., Varad, N., . . . Mahipal, S. S. (2022). Heavy Metal Contamination of Water and Their Toxic Effect on Living Organisms. In D. Dr. Daniel & O. Prof. Danielle Palma De (Eds.) (2018), *The Toxicity of Environmental Pollutants* (pp. Ch. 4). Rijeka: IntechOpen.

Appenroth, K.-J. (2010). Definition of "Heavy Metals" and Their Role in Biological Systems *Soil Heavy Metals* (pp. 19-29). Berlin, Heidelberg: Springer Berlin Heidelberg.

Awad, F. S., AbouZied, K. M., Abou El-Maaty, W. M., El-Wakil, A. M., & Samy El-Shall, M. (2018). Effective removal of mercury(II) from aqueous solutions by chemically modified graphene oxide nanosheets. *Arabian Journal of Chemistry*.

Ayawei Nimibofa, E. A. N., Abasi Yameso Cyprain & Wankasi Donbebe. (2018). Fullerenes: Synthesis and Applications. *Jurnal of Materials Science Research, 7*(3), 16.

Ayyaru, S., & Ahn, Y.-H. (2017). Application of sulfonic acid group functionalized graphene oxide to improve hydrophilicity, permeability, and antifouling of PVDF nanocomposite ultrafiltration membranes. *Journal of Membrane Science, 525*, 210-219.

A Zhitkovich (2005). Importance of chromium-DNA adducts in mutagenicity and toxicity of chromium (VI). . Chem Res Toxicol, 18(1), 8.

Ayawei, N., Ebelegi, A. N., & Wankasi, D. - Modelling and Interpretation of Adsorption Isotherms.

Baffour-Awuah, E., Akinlabi, S. A., Jen, T. C., Hassan, S., Okokpujie, I. P., & Ishola, F. (2021). Characteristics of Palm Kernel Shell and Palm Kernel Shell-Polymer Composites: A Review. *IOP Conference Series: Materials Science and Engineering, 1107*(1), 012090.

Bock, P., Nousiainen, P., Elder, T., Blaukopf, M., Amer, H., Zirbs, R., . . . Gierlinger, N. (2020). Infrared and Raman spectra of lignin substructures: Dibenzodioxocin. *Journal of Raman Spectroscopy, 51*(3), 422-431.

Bolisetty, S., Peydayesh, M., & Mezzenga, R. (2019). Sustainable technologies for water purification from heavy metals: review and analysis. *Chemical Society Reviews, 48*(2), 463-487.

Bradder, P., Ling, S. K., Wang, S., & Liu, S. (2011). Dye Adsorption on Layered Graphite Oxide. *Journal of Chemical & Engineering Data, 56*(1), 138-141.

Bolisetty, S., Peydayesh, M., & Mezzenga, R. (2019). Sustainable technologies for water purification from heavy metals: review and analysis. *Chemical Society Reviews, 48*(2), 463-487.

Bouamama Abbar a, A. A., ∗, Stéphane Marcotte b, Anne Pantet a,, & Nasre-Dine Ahfir a, L. B. a., Davy Duriatti c. (2017). Experimental investigation on removal of heavy metals (Cu2+ , Pb2+ and Zn2+) from aqueous solution by flax fibres. *Process Safety and Environmental Protection, 109*, 8.

Bozbaş, S. K., & Boz, Y. (2016). Low-cost biosorbent: Anadara inaequivalvis shells for removal of Pb(II) and Cu(II) from aqueous solution. *Process Safety and Environmental Protection, 103*, 144-152.

Bradder, P., Ling, S. K., Wang, S., & Liu, S. (2011). Dye Adsorption on Layered Graphite Oxide. *Journal of Chemical & Engineering Data, 56*(1), 138-141.

Bakry, R., Vallant, R. M., Najam-ul-Haq, M., Rainer, M., Szabo, Z., Huck, C. W., & Bonn, G. K. (2007). Medicinal applications of fullerenes. *International journal of nanomedicine, 2*(4), 639-649.

Bilu Liu, F. W., Hui Gui, Ming Zheng, and Chongwu Zhou. (2017). Chirality-Controlled Synthesis and Applications of Single-Wall Carbon Nanotubes. *ACS Nano, 11*(1), 23.

Bozbaş, S. K., & Boz, Y. (2016). Low-cost biosorbent: Anadara inaequivalvis shells for removal of Pb(II) and Cu(II) from aqueous solution. *Process Safety and Environmental Protection, 103*, 144-152.

Bradder, P., Ling, S. K., Wang, S., & Liu, S. (2011). Dye Adsorption on Layered Graphite Oxide. *Journal of Chemical & Engineering Data, 56*(1), 138-141.

Brita, T. A. D. S., Muyssen; Karel, A. C Janssen, Colin R. . (2006). Mechanisms of chronic waterborne Zn toxicity in Daphnia magna. *Aquatic Toxicology., 77*(4), 9.

Brunet, L., Lyon, D. Y., Hotze, E. M., Alvarez, P. J. J., & Wiesner, M. R. (2009). Comparative Photoactivity and Antibacterial Properties of C60 Fullerenes and Titanium Dioxide Nanoparticles. *Environmental Science & Technology, 43*(12), 4355-4360.

Burakov, A. E., Galunin, E. V., Burakova, I. V., Kucherova, A. E., Agarwal, S., Tkachev, A. G., & Gupta, V. K. (2018). Adsorption of heavy metals on conventional and nanostructured materials for wastewater treatment purposes: A review. *Ecotoxicology and Environmental Safety, 148*, 702-712.

Bozbaş, S. K., & Boz, Y. (2016). Low-cost biosorbent: Anadara inaequivalvis shells for removal of Pb(II) and Cu(II) from aqueous solution. *Process Safety and Environmental Protection, 103*, 144-152.

Baruthio, F. (1992). Toxic effects of chromium and its compounds. *Biol Trace Elem Res, 32*, 145-153.

Bock, P., Nousiainen, P., Elder, T., Blaukopf, M., Amer, H., Zirbs, R., . . . Gierlinger, N. (2020). Infrared and Raman spectra of lignin substructures: Dibenzodioxocin. *Journal of Raman Spectroscopy, 51*(3), 422-431.

Bradder, P., Ling, S. K., Wang, S., & Liu, S. (2011). Dye Adsorption on Layered Graphite Oxide. *Journal of Chemical & Engineering Data, 56*(1), 138-141.

Brunet, L., Lyon, D. Y., Hotze, E. M., Alvarez, P. J. J., & Wiesner, M. R. (2009). Comparative Photoactivity and Antibacterial Properties of C60 Fullerenes and Titanium Dioxide Nanoparticles. *Environmental Science & Technology, 43*(12), 4355-4360.

Bansal, N. (2018). Industrial Development and Challenges of Water Pollution in Coastal Areas: The Case of Surat, India. *IOP Conference Series: Earth and Environmental Science, 120*, 012001.

Bhuyan, M. S., Bakar, M. A., Rashed-Un-Nabi, M., Senapathi, V., Chung, S. Y., & Islam, M. S. (2019). Monitoring and assessment of heavy metal contamination in surface water and sediment of the Old Brahmaputra River, Bangladesh. *Applied Water Science, 9*(5), 125.

Chen, C.-J., Zhu, W., Chao, J.-H., Shang, A., Lee, Y. G., Liu, R., . . . Hoffman, R. C. (2019). Study of thermal and spatial dependent electric field-induced phase transition in relaxor ferroelectric crystals using Raman spectroscopy. *Journal of Alloys and Compounds, 804*, 35-41.

Cooper, A. M., Felix, D., Alcantara, F., Zaslavsky, I., Work, A., Watson, P. L., . . . Schroeder, J. I. (2020). Monitoring and mitigation of toxic heavy metals and arsenic accumulation in food crops: A case study of an urban community garden. *Plant Direct, 4*(1).

Coyte, R. M., McKinley, K. L., Jiang, S., Karr, J., Dwyer, G. S., Keyworth, A. J., . . . Vengosh, A. (2020). Occurrence and distribution of hexavalent chromium in groundwater from North Carolina, USA. *Science of The Total Environment, 711*, 135135.

Crawford, C. B., & Quinn, B. (2017). 6 - The interactions of microplastics and chemical pollutants. In C. B. Crawford & B. Quinn (Eds.), *Microplastic Pollutants* (pp. 131-157): Elsevier.

Chen, C.-J., Zhu, W., Chao, J.-H., Shang, A., Lee, Y. G., Liu, R., . . . Hoffman, R. C. (2019). Study of thermal and spatial dependent electric field-induced phase transition in relaxor ferroelectric crystals using Raman spectroscopy. *Journal of Alloys and Compounds, 804*, 35-41.

Chen, X., & Tian, Z. (2021). Adsorption process and mechanism of heavy metal ions by different components of cells, using yeast (Pichia pastoris) and Cu(2+) as biosorption models. *11*(28), 17080-17091.

Cooper, A. M., Felix, D., Alcantara, F., Zaslavsky, I., Work, A., Watson, P. L., .Schroeder, J. I. (2020). Monitoring and mitigation of toxic heavy metals and arsenic accumulation in food crops: A case study of an urban community garden. *Plant Direct, 4*(1).

Cimxe, M., C. A.Abdellaoui, Youness, Abatal, Mohamed, Vargas, Joel, Santiago, Arlette A.Barr, n-Zambrano, Jes, s Alberto. (2019). Eco-Efficient Biosorbent Based on Leucaena leucocephala Residues for the Simultaneous Removal of Pb(II) and Cd(II) Ions from Water System: Sorption and Mechanism. *Bioinorganic Chemistry and Applications, 2019*, 13

Chen, C.-J., Zhu, W., Chao, J.-H., Shang, A., Lee, Y. G., Liu, R., . . . Hoffman, R. C. (2019). Study of thermal and spatial dependent electric field-induced phase transition in relaxor ferroelectric crystals using Raman spectroscopy. *Journal of Alloys and Compounds, 804*, 35-41.

Cimxe, M., C. A.Abdellaoui, Youness, Abatal, Mohamed, Vargas, Joel, Santiago, Arlette A.Barr, n-Zambrano, Jes, s Alberto. (2019). Eco-Efficient Biosorbent Based on Leucaena leucocephala Residues for the Simultaneous Removal of Pb(II) and Cd(II) Ions from Water System: Sorption and Mechanism. *Bioinorganic Chemistry and Applications, 2019*, 13.

Czikkely, M., Neubauer, E., Fekete, I., Ymeri, P., & Fogarassy, C. (2018). Review of Heavy Metal Adsorption Processes by Several Organic Matters from Wastewaters. *Water, 10*(10), 1377.

Cao, F., Lian, C., Yu, J., Yang, H., & Lin, S. (2019). Study on the adsorption performance and competitive mechanism for heavy metal contaminants removal using novel multi-pore activated carbons derived from recyclable long-root Eichhornia crassipes. *Bioresource Technology*..

Cha, C., Shin, S. R., Annabi, N., Dokmeci, M. R., & Khademhosseini, A. (2013). Carbon-based nanomaterials: multifunctional materials for biomedical engineering. *ACS Nano, 7*(4), 2891-2897.

Chao, H. N. T.-P. (2018). Adsorption and desorption of potentially toxic metals on modified biosorbents through new green grafting process. *Environmental science and pollution research, 25,* (13), 19.

Chaudhari, A. A., Ashmore, D. a., Nath, S. D., Kate, K., Dennis, V., Singh, S. R., . . . Pillai, S. R. (2016). A novel covalent approach to bio-conjugate silver coated single walled carbon nanotubes with antimicrobial peptide. *Journal of nanobiotechnology*, *14*(1), 58-58..

Choi, W., Lahiri, I., Seelaboyina, R., & Kang, Y. S. (2010). Synthesis of Graphene and Its Applications: A Review. *Critical Reviews in Solid State and Materials Sciences, 35*(1), 52-71. doi: 10.1080/10408430903505036.

Cimxe, M., C. A.Abdellaoui, Youness, Abatal, Mohamed, Vargas, Joel, Santiago, Arlette A.Barr, n-Zambrano, Jes, s Alberto. (2019). Eco-Efficient Biosorbent Based on Leucaena leucocephala Residues for the Simultaneous Removal of Pb(II) and Cd(II) Ions from Water System: Sorption and Mechanism. *Bioinorganic Chemistry and Applications, 2019*, 13.

Culetu, A., Gherase, D., Sîrbu, F., & Catrinel, A. (2014). *Environmental Applications of Carbon-Based Nanomaterials. Acetylcholinesterase Biosensors for Organophosphate Pesticide Analysis*.

Czikkely, M., Neubauer, E., Fekete, I., Ymeri, P., & Fogarassy, C. (2018). Review of Heavy Metal Adsorption Processes by Several Organic Matters from Wastewaters. *Water, 10*(10), 1377.

Dong, L., Liu, W., Yu, Y., Hou, L. a., Gu, P., & Chen, G. (2019). Preparation, characterization, and application of macroporous activated carbon (MAC) suitable for the BAC water treatment process. *Science of The Total Environment, 647*, 1359-1367.

Donald L. Pavia, G.M.L., George S. Kriz & James R. Vyvyan, *Inroduction to Spectroscopy* 4ed. 2009, United States of America: Brooks/Cole Cengage Learning.

Dorniani, D., Saifullah, B., Barahuie, F., Arulselvan, P., Hussein, M. Z. B., Fakurazi, S., & Twyman, L. J. (2016). Graphene Oxide-Gallic Acid Nanodelivery System for Cancer Therapy. *Nanoscale Research Letters, 11*(1), 491.

Duan, Q., Lee, J., Liu, Y., & Qi, H. (2016). Preparation and Photocatalytic Performance of MWCNTs/TiO2 Nanocomposites for Degradation of Aqueous Substrate. *Journal of Chemistry, 2016*, 8.

Donald L. Pavia, G. M. L., George S. Kriz & James R. Vyvyan. (2009). *Inroduction to Spectroscopy* (4 ed.). United States of America: Brooks/Cole Cengage Learning.

Fu, F., & Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environmental Management*, *92*(3), 407-418. doi: https://doi.org/10.1016/j.jenvman.2010.11.011.

El Maguana, Y., Elhadiri, N., Bouchdoug, M., Benchanaa, M., & Jaouad, A. (2019). Activated Carbon from Prickly Pear Seed Cake: Optimization of Preparation Conditions Using Experimental Design and Its Application in Dye Removal. *International Journal of Chemical Engineering, 2019*, 12.

Elsehly, E. M. I., Chechenin, N. G., Bukunov, K. A., Makunin, A. V., Priselkova, A. B., Vorobyeva, E. A., & Motaweh, H. A. (2015). Removal of iron and manganese from aqueous solutions using carbon nanotube filters. *Water Supply*, *16*(2), 347-353.

Egbosiuba, T. C., Abdulkareem, A. S., Kovo, A. S., Afolabi, E. A., Tijani, J. O., Bankole, M. T., . . . Roos, W. D. (2021). Adsorption of Cr(VI), Ni(II), Fe(II) and Cd(II) ions by KIAgNPs decorated MWCNTs in a batch and fixed bed process. *Scientific Reports*, *11*(1), 75..

Ekpete, O. A., Marcus, A. C., & Osi, V. (2017). Preparation and Characterization of Activated Carbon Obtained from Plantain (Musa paradisiaca) Fruit Stem. *Journal of Chemistry, 2017*, 8635615..

El-Dib, F. I., Mohamed, D. E., El-Shamy, O. A. A., & Mishrif, M. R. (2020). Study the adsorption properties of magnetite nanoparticles in the presence of different synthesized surfactants for heavy metal ions removal. *Egyptian Journal of Petroleum*, *29*(1), 1-7.

Egbosiuba, T. C., Abdulkareem, A. S., Kovo, A. S., Afolabi, E. A., Tijani, J. O., Bankole, M. T., . . . Roos, W. D. (2021). Adsorption of Cr(VI), Ni(II), Fe(II) and Cd(II) ions by KIAgNPs decorated MWCNTs in a batch and fixed bed process. *Scientific Reports*, *11*(1), 75.

Farghali, A. A., Abdel Tawab, H. A., Abdel Moaty, S. A., & Khaled, R. (2017). Functionalization of acidified multi-walled carbon nanotubes for removal of heavy metals in aqueous solutions. *Journal of Nanostructure in Chemistry*, *7*(2), 101-111.

Foo, K. Y., & Hameed, B. H. (2011). The environmental applications of activated carbon/zeolite composite materials. *Adv Colloid Interface Sci*, *162*(1-2), 22-28.

Fosmire, G. J. Zinc Toxicity. *The American Journal of Clinical Nutrition 1990*, *51*(2), 3.

Friedlingstein, P. S., S.; Plattner, G-K. (2011). Long-term climate implications of twenty-first century options for carbon dioxide emission mitigation. *Nature Climate Change, 1*(9), 5.

Fu, F., & Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environmental Management, 92*(3), 407-418.

Foo, K. Y., & Hameed, B. H. (2011). The environmental applications of activated carbon/zeolite composite materials. *Adv Colloid Interface Sci, 162*(1-2), 22-28.

Genc, R., Alas, M. O., Harputlu, E., Repp, S., Kremer, N., Castellano, M., . . . Erdem, E. (2017). High-Capacitance Hybrid Supercapacitor Based on Multi-Colored Fluorescent Carbon-Dots. *Scientific Reports, 7*(1), 11222.

Ghosh, A., Subrahmanyam, K. S., Krishna, K. S., Datta, S., Govindaraj, A., Pati, S. K., & Rao, C. N. R. (2008). Uptake of H2 and CO2 by Graphene. *The Journal of Physical Chemistry C, 112*(40), 15704-15707.

Guo, M., Qiu, G., & Song, W. (2010). Poultry litter-based activated carbon for removing heavy metal ions in water. *Waste Management, 30*(2), 308-315.

Guo, T., Bulin, C., Li, B., Zhao, Z., Yu, H., Sun, H., . . . Zhang, B. (2018). Efficient removal of aqueous Pb(II) using partially reduced graphene oxide-Fe3O4. *Adsorption Science & Technology, 36*(3-4), 1031-1048.

Gupta, R. K., Dunderdale, G. J., England, M. W., & Hozumi, A. (2017). Oil/water separation techniques: a review of recent progresses and future directions. *Journal of Materials Chemistry A, 5*(31), 16025-16058.

Gupta, V. K., Agarwal, S., & Saleh, T. A. (2011a). Chromium removal by combining the magnetic properties of iron oxide with adsorption properties of carbon nanotubes. *Water Res, 45*(6), 2207-2212.

Gupta, V. K., Agarwal, S., & Saleh, T. A. (2011b). Synthesis and characterization of alumina-coated carbon nanotubes and their application for lead removal. *J Hazard Mater, 185*(1), 17-23.

Gupta, S., Garg, D., & Kumar, A. (2022). Cadmium biosorption using Aloe. barbadensis Miller leaves waste powder treated with sodium bicarbonate. *Cleaner Waste Systems, 3*, 100032.

Gyana Ranjan ROUT, P. D. (2003). Effect of metal toxicity on plant growth and metabolism: I. Zinc. *Agronomie, 23*(3), 11.

Gillespie, R. J., & Robinson, E. A. (1963). The Sulphur–Oxygen Bond In Sulphuryl And Thionyl Compounds: Correlation Of Stretching Frequencies And Force Constants With Bond Lengths, Bond Angles, And Bond Orders. *Canadian Journal Of Chemistry, 41*(8), 2074-2085.

Gupta, V. K., Agarwal, S., & Saleh, T. A. (2011). Synthesis and characterization of alumina-coated carbon nanotubes and their application for lead removal. *J Hazard Mater, 185*(1), 17-23.

Gebeyehu, H. R., & Bayissa, L. D. (2020). Levels of heavy metals in soil and vegetables and associated health risks in Mojo area, Ethiopia. *PLOS ONE, 15*(1), e0227883.

Hamzezadeh, A., Rashtbari, Y., Afshin, S., Morovati, M., & Vosoughi, M. (2020). Application of low-cost material for adsorption of dye from aqueous solution. *International Journal of Environmental Analytical Chemistry*, 1-16.

Hasan, S., Al Ali, H., Al-Qubaisi, M., Zobir Hussein, M., Ismail, M., Zainal, Z., & Nazrul Hakim, M. (2012). Controlled-release formulation of antihistamine based on cetirizine zinc-layered hydroxide nanocomposites and its effect on histamine release from basophilic leukemia (RBL-2H3) cells. *Int J Nanomedicine, 7*, 3351-3363.

Hegazy, A. K., Abdel-Ghani, N. T., & El-Chaghaby, G. A. (2014). Adsorption of phenol onto activated carbon from Rhazya stricta: determination of the optimal experimental parameters using factorial design. *Applied Water Science, 4*(3), 273-281. doi:

Hernández-Monje, D., Giraldo, L., & Moreno-Piraján, J. C. (2018). Study of Hexane Adsorption on Activated Carbons with Differences in Their Surface Chemistry. *Molecules (Basel, Switzerland), 23*(2), 476.

Ho, Y. S., & Ofomaja, A. E. (2006). Pseudo-second-order model for lead ion sorption from aqueous solutions onto palm kernel fiber. *J Hazard Mater, 129*(1-3), 137-142.

Hegazi, H. A. (2013). Removal of heavy metals from wastewater using agricultural and industrial wastes as adsorbents. *HBRC Journal, 9*(3), 276-282.

Herold, F., Leubner, O., Jeschonek, K., Hess, C., Drochner, A., Qi, W., & Etzold, B. J. M. (2021). Methodology for the identification of carbonyl absorption maxima of carbon surface oxides in DRIFT spectra. *Carbon Trends, 3*, 100020.

Holmes, P., James, K. A., & Levy, L. S. (2009). Is low-level environmental mercury exposure of concern to human health? *Sci Total Environ, 408*(2), 171-182.

Hong, J., Xie, J., Mirshahghassemi, S., & Lead, J. (2020). Metal (Cd, Cr, Ni, Pb) removal from environmentally relevant waters using polyvinylpyrrolidone-coated magnetite nanoparticles. *RSC Adv, 10*(6), 3266-3276.

Huang, Y., Liu, H., Yuan, H., Zhan, H., Zhuang, X., Yuan, S., . . . Wu, C. (2018). Relevance between chemical structure and pyrolysis behavior of palm kernel shell lignin. *Science of The Total Environment, 633*, 785-795.

Hung, M.-C., Yuan, S.-Y., Chang, S. I., Liao, J.-W., Ko, T.-H., & Cheng, C.-L. (2014). Evaluation of active carbon fibers used in cell biocompatibility and rat cystitis treatment. *Carbon, 68*, 628-637.

Hegazi, H. A. (2013). Removal of heavy metals from wastewater using agricultural and industrial wastes as adsorbents. *HBRC Journal, 9*(3), 276-282.

Hung, M.-C., Yuan, S.-Y., Chang, S. I., Liao, J.-W., Ko, T.-H., & Cheng, C.-L. (2014). Evaluation of active carbon fibers used in cell biocompatibility and rat cystitis treatment. *Carbon, 68*, 628-637.

Huang, Q., Zhao, J., Liu, M., Li, Y., Ruan, J., Li, Q., . . . Wei, Y. (2018). Synthesis of polyacrylamide immobilized molybdenum disulfide (MoS2@PDA@PAM) composites via mussel-inspired chemistry and surface-initiated atom transfer radical polymerization for removal of copper (II) ions. *Journal of the Taiwan Institute of Chemical Engineers, 86*, 174-184.

Han, X., Li, S., Peng, Z., Al-Yuobi, A. O., Omar Bashammakh, A. S., El-Shahawi, M. S., & Leblanc, R. M. (2016). Interactions between Carbon Nanomaterials and Biomolecules. *J Oleo Sci, 65*(1), 1-7.

Hankins, N. P., Lu, N., & Hilal, N. (2006). Enhanced removal of heavy metal ions bound to humic acid by polyelectrolyte flocculation. *Separation and Purification Technology, 51*(1), 48-56. doi: https://doi.org/10.1016/j.seppur.2005.12.022.

Hong, X., Xia, M., Shi, M., Liu, C., Yan, Y., Tao, Y., . . . Wang, F. (2023). Investigation of the adsorption performance and mechanism of 2-mercaptoethane sulfonic acid intercalated modified layered double hydroxide on heavy metal ions. *Journal of Colloid and Interface Science, 629*, 948-959.

Huang, Q., Zhao, J., Liu, M., Chen, J., Zhu, X., Wu, T., . . . Wei, Y. (2018). Preparation of polyethylene polyamine@tannic acid encapsulated MgAl-layered double hydroxide for the efficient removal of copper (II) ions from aqueous solution. *Journal of the Taiwan Institute of Chemical Engineers, 82*, 92-101.

Huang, Q., Zhao, J., Liu, M., Li, Y., Ruan, J., Li, Q., . . . Wei, Y. (2018). Synthesis of polyacrylamide immobilized molybdenum disulfide (MoS2@PDA@PAM) composites via mussel-inspired chemistry and surface-initiated atom transfer radical polymerization for removal of copper (II) ions. *Journal of the Taiwan Institute of Chemical Engineers, 86*, 174-184.

Hung, M.-C., Yuan, S.-Y., Chang, S. I., Liao, J.-W., Ko, T.-H., & Cheng, C.-L. (2014). Evaluation of active carbon fibers used in cell biocompatibility and rat cystitis treatment. *Carbon, 68*, 628-637.

Hung Thang, B., Dinh Quang, L., Manh Hong, N., Khoi, P. H., & Minh, P. N. (2014). Application of Multiwalled Carbon Nanotube Nanofluid for 450 W LED Floodlight. *Journal of Nanomaterials, 2014*, 6. doi: 10.1155/2014/347909.

Ibrahim Umar Salihi, S. R. M. K. a. H. H. M., & Ismail, A. F. (2018). *Copper Metal Removal using Sludge Activated Carbon Derived from Wastewater Treatment Sludge*. Paper presented at the MATEC Web of Conferences 203, 03009 (2018) ICCOEE 2018.

Ismail, A., Harmuni, H., & Mohd, R. R. M. A. Z. (2017). Removal of iron and manganese using granular activated carbon and zeolite in artificial barrier of riverbank filtration. *AIP Conference Proceedings, 1835*(1), 020056.

Issabayeva, G., Aroua, M. K., & Sulaiman, N. M. (2010). Study on palm shell activated carbon adsorption capacity to remove copper ions from aqueous solutions. *Desalination, 262*(1), 94-98.

Ibrahim, W. M., Hassan, A. F., & Azab, Y. A. (2016). Biosorption of toxic heavy metals from aqueous solution by Ulva lactuca activated carbon. *Egyptian Journal of Basic and Applied Sciences, 3*(3), 241-249.

Jacobs, J. T., SM. . (2005). *Overview of chromium(VI) in the environment: background and history.*: Chromium (VI) Handbook. Boca Raton, Fl:CRC Press.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdiscip Toxicol, 7*(2), 60-72.

Jin, Q.-Q., Zhu, X.-H., Xing, X.-Y., & Ren, T.-Z. (2012). Adsorptive Removal of Cationic Dyes from Aqueous Solutions Using Graphite Oxide. *Adsorption Science & Technology, 30*(5), 437-447.

Jang, S. S., S.; Lim, J.H.; Kim, H.S.; Phan, B.T.; Ha, K.-T.; Park, S.; Park, K.H. . (2020). Application of Various Metal-Organic Frameworks (MOFs) as Catalysts for Air and Water Pollution Environmental Remediation.. Catalysts 10, no. 2: 195.

Kaneko, K., Ishii, C., Arai, T., & Suematsu, H. (1993). Defect-associated microporous nature of fullerene C60 crystals. *The Journal of Physical Chemistry, 97*(26), 6764-6766.

Karthikeyan, T., Rajgopal, S., & Miranda, L. R. (2005). Chromium(VI) adsorption from aqueous solution by Hevea Brasilinesis sawdust activated carbon. *J Hazard Mater, 124*(1-3), 192-199.

Kaviani, S., Tayurskii, D. A., Nedopekin, O. V., & Piyanzina, I. (2022). DFT insight into Cd2+, Hg2+, Pb2+, Sn2+, As3+, Sb3+, and Cr3+ heavy metal ions adsorption onto surface of bowl-like B30 nanosheet. *Journal of Molecular Liquids, 365*, 120131.

Khan, Z., Chetia, T. R., Vardhaman, A. K., Barpuzary, D., Sastri, C. V., & Qureshi, M. (2012). Visible light assisted photocatalytic hydrogen generation and organic dye degradation by CdS–metal oxide hybrids in presence of graphene oxide. *RSC Advances, 2*(32), 12122-12128.

Katoch, A., Goyal, N., & Gautam, S. (2019). Applications and advances in coordination cages: Metal-Organic Frameworks. *Vacuum, 167*, 287-300.

Khamkeaw, A., Asavamongkolkul, T., Perngyai, T., Jongsomjit, B., & Phisalaphong, M. (2020). Interconnected Micro, Meso, and Macro Porous Activated Carbon from Bacterial Nanocellulose for Superior Adsorption Properties and Effective Catalytic Performance. *Molecules, 25*(18), 4063.

Kongsuwan, A., Patnukao, P., & Pavasant, P. (2009). Binary component sorption of Cu(II) and Pb(II) with activated carbon from Eucalyptus camaldulensis Dehn bark. *Journal of Industrial and Engineering Chemistry, 15*(4), 465-470.

Konicki, W., Aleksandrzak, M., Moszyński, D., & Mijowska, E. (2017). Adsorption of anionic azo-dyes from aqueous solutions onto graphene oxide: Equilibrium, kinetic and thermodynamic studies. *Journal of Colloid and Interface Science, 496*, 188-200.

Kroto, H. W., Heath, J. R., O'Brien, S. C., Curl, R. F., & Smalley, R. E. (1985). C60: Buckminsterfullerene. *Nature, 318*, 162. 0.

Kula, I., Ugurlu, M., Karaoglu, H., & Celik, A. (2008). Adsorption of Cd(II) ions from aqueous solutions using activated carbon prepared from olive stone by ZnCl2 activation. *Bioresour Technol, 99*(3), 492-501.

Kulkarni, R. M., Dhanyashree, J. K., Varma, E., & Sirivibha, S. P. (2022). Batch and continuous packed bed column studies on biosorption of nickel (II) by sugarcane bagasse. *Results in Chemistry, 4*, 100328.

Kyzas, G. Z., Deliyanni, E. A., & Matis, K. A. (2014). Graphene oxide and its application as an adsorbent for wastewater treatment. *Journal of Chemical Technology & Biotechnology, 89*(2), 196-205.

Karri, R. R., & Sahu, J. N. (2018). Modeling and optimization by particle swarm embedded neural network for adsorption of zinc (II) by palm kernel shell based activated carbon from aqueous environment. *J Environ Manage, 206*, 178-191.

Karri, R. R., & Sahu, J. N. (2018). Process optimization and adsorption modeling using activated carbon derived from palm oil kernel shell for Zn (II) disposal from the aqueous environment using differential evolution embedded neural network. *Journal of Molecular Liquids, 265*, 592-602.

Kura, A. U., Saifullah, B., Cheah, P. S., Hussein, M. Z., Azmi, N., & Fakurazi, S. (2015). Acute oral toxicity and biodistribution study of zinc-aluminium-levodopa nanocomposite. *Nanoscale Res Lett, 10*(105), 015-0742.

Karri, R. R., & Sahu, J. N. (2018). Modeling and optimization by particle swarm embedded neural network for adsorption of zinc (II) by palm kernel shell based activated carbon from aqueous environment. *J Environ Manage, 206*, 178-191.

Karri, R. R., & Sahu, J. N. (2018). Process optimization and adsorption modeling using activated carbon derived from palm oil kernel shell for Zn (II) disposal from the aqueous environment using differential evolution embedded neural network. *Journal of Molecular Liquids, 265*, 592-602.

Kondo, T., Inoue, H., & Minoshima, K. (2020). Thickness dependency of creep crack propagation mechanisms in submicrometer-thick gold films investigated using in situ FESEM and EBSD analysis. *Materials Science and Engineering: A, 790*, 139621.

Lazzarini, A., Piovano, A., Pellegrini, R., Agostini, G., Rudić, S., Lamberti, C., & Groppo, E. (2016). Graphitization of Activated Carbons: A Molecular-level Investigation by INS, DRIFT, XRD and Raman Techniques. *Physics Procedia, 85*, 20-26.

Li, Q., Wang, L., Xu, R., Yang, Y., Yin, H., Jin, S., & Jiang, T. (2022). Potentiality of phosphorus−accumulating organisms biomasses in biosorption of Cd(II), Pb(II), Cu(II) and Zn(II) from aqueous solutions: Behaviors and mechanisms. *Chemosphere, 303*, 135095.

Liu, R., Liu, D., Li, J., Liu, S., Liu, Z., Gao, L.Ao, S. (2020). Improved understanding of the sulfidization mechanism in cerussite flotation: An XPS, ToF-SIMS and FESEM investigation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 595*, 124508.

Li, Z., Wang, L., Meng, J., Liu, X., Xu, J., Wang, F., & Brookes, P. (2018). Zeolite-supported nanoscale zero-valent iron: New findings on simultaneous adsorption of Cd(II), Pb(II), and As(III) in aqueous solution and soil. *Journal of Hazardous Materials, 344*, 1-11.

Li, Z., Yang, Y., Jáuregui-Haza, U., Guo, Z., & Campos, L. C. (2019). The impact of humic acid on metaldehyde adsorption onto powdered activated carbon in aqueous solution. *RSC Advances, 9*(1), 11-22.

Lamberti, M., Pedata, P., Sannolo, N., Porto, S., De Rosa, A., & Caraglia, M. (2015). Carbon nanotubes: Properties, biomedical applications, advantages and risks in patients and occupationally-exposed workers. *International Journal of Immunopathology and Pharmacology, 28*(1), 4-13.

Lee, K., Mazare, A., & Schmuki, P. (2014). One-Dimensional Titanium Dioxide Nanomaterials: Nanotubes. *Chem Rev, 114*(19), 9385-9454. doi: 10.1021/cr500061m.

Lazzarini, A., Piovano, A., Pellegrini, R., Agostini, G., Rudić, S., Lamberti, C., & Groppo, E. (2016). Graphitization of Activated Carbons: A Molecular-level Investigation by INS, DRIFT, XRD and Raman Techniques. *Physics Procedia, 85*, 20-26.

Lei, B., Xie, H., Chen, S., Liu, B., & Zhou, G. (2020). Control of pore structure and surface chemistry of activated carbon derived from waste Zanthoxylum

bungeanum branches for toluene removal in air. *Environmental Science and Pollution Research, 27*(21), 27072-27092. doi: 10.1007/s11356-020-09115-2.

Li, Z., Wang, L., Meng, J., Liu, X., Xu, J., Wang, F., & Brookes, P. (2018). Zeolite-supported nanoscale zero-valent iron: New findings on simultaneous adsorption of Cd(II), Pb(II), and As(III) in aqueous solution and soil. *Journal of Hazardous Materials, 344*, 1-11. doi: https://doi.org/10.1016/j.jhazmat.2017.09.036.

Liakos, E. V., Mone, M., Lambropoulou, D. A., Bikiaris, D. N., & Kyzas, G. Z. (2021). Adsorption Evaluation for the Removal of Nickel, Mercury, and Barium Ions from Single-Component and Mixtures of Aqueous Solutions by Using an Optimized Biobased Chitosan Derivative. *Polymers, 13*(2), 232.

Liu, X., Xu, X., Dong, X., & Park, J. (2020). Competitive Adsorption of Heavy Metal Ions from Aqueous Solutions onto Activated Carbon and Agricultural Waste Materials. *Polish Journal of Environmental Studies, 29*(1), 749-761. doi: 10.15244/pjoes/104455.

Lu, Z., Sun, W., Li, C., Cao, W., Jing, Z., Li, S., . . . Liu, S. (2020). Effect of granular activated carbon pore-size distribution on biological activated carbon filter performance. *Water Res, 177*(115768), 3.

Luo, Y., Li, D., Chen, Y., Sun, X., Cao, Q., & Liu, X. (2019). The performance of phosphoric acid in the preparation of activated carbon-containing phosphorus species from rice husk residue. *Journal of Materials Science, 54*(6), 5008-5021.

Lazzarini, A., Piovano, A., Pellegrini, R., Agostini, G., Rudić, S., Lamberti, C., & Groppo, E. (2016). Graphitization of Activated Carbons: A Molecular-level Investigation by INS, DRIFT, XRD and Raman Techniques. *Physics Procedia, 85*, 20-26.

Liu, X., Xu, X., Dong, X., & Park, J. (2020). Competitive Adsorption of Heavy Metal Ions from Aqueous Solutions onto Activated Carbon and Agricultural Waste Materials. *Polish Journal of Environmental Studies, 29*(1), 749-761.

Loh, K. P., Ho, D., Chiu, G. N. C., Leong, D. T., Pastorin, G., & Chow, E. K.-H. (2018). Clinical Applications of Carbon Nanomaterials in Diagnostics and Therapy. *Advanced Materials, 30*(47), 1802368.

Lu, X., He, J., Jing, R., Tao, P., Nie, R., Zhou, D., & Xia, Q. (2017). Microwave-activated Ni/carbon catalysts for highly selective hydrogenation of nitrobenzene to cyclohexylamine. *Scientific reports, 7*(1), 2676-2676.

Lee, Z. H., Lee, K. T., Bhatia, S., & Mohamed, A. R. (2012). Post-combustion carbon dioxide capture: Evolution towards utilization of nanomaterials. *Renewable and Sustainable Energy Reviews, 16*(5), 2599-2609.

Lefebvre, J., Ding, J., Li, Z., Finnie, P., Lopinski, G., & Malenfant, P. R. L. (2017). High-Purity Semiconducting Single-Walled Carbon Nanotubes: A Key Enabling Material in Emerging Electronics. *Acc Chem Res, 50*(10), 2479-2486.

Li, B., Liu, T., Wang, Y., & Wang, Z. (2012). ZnO/graphene-oxide nanocomposite with remarkably enhanced visible-light-driven photocatalytic performance. *J Colloid Interface Sci, 377*(1), 114-121.

Li, H., Ha, C.-S., & Kim, I. (2009). Fabrication of Carbon Nanotube/SiO(2) and Carbon Nanotube/SiO(2)/Ag Nanoparticles Hybrids by Using Plasma Treatment. *Nanoscale research letters, 4*(11), 1384-1388.

Li, J., Xing, X., Li, J., Shi, M., Lin, A., Xu, C., . . . Li, R. (2018). Preparation of thiol-functionalized activated carbon from sewage sludge with coal blending for heavy metal removal from contaminated water. *Environmental Pollution, 234*, 677-683.

Liu, Y., Huang, H., Gan, D., Guo, L., Liu, M., Chen, J., . . . Wei, Y. (2018). A facile strategy for preparation of magnetic graphene oxide composites and their potential for environmental adsorption. *Ceramics International, 44*(15), 18571-18577.

Lo, S. F., Wang, S.Y., Tsai, M.J., Lin, L.D. (2012). Adsorption capacity and removal efficiency of heavy metal ions by Moso and Ma bamboo activated carbons. . *Chem. Eng. Res. Des., 90*(9), 10.

Lucena, R., Simonet, B. M., Cardenas, S., & Valcarcel, M. (2011). Potential of nanoparticles in sample preparation. *J Chromatogr A, 28*(4), 620-637.

Luo, C., Tian, Z., Yang, B., Zhang, L., Yan, S. (2013). Manganese dioxide/iron oxide/acid oxidized multi-walled carbon nanotube magnetic nanocomposite for enhanced hexavalent chromium removal. . *Chem. Eng. J., 234*, 11.

Liu, Y., Huang, H., Gan, D., Guo, L., Liu, M., Chen, J., Wei, Y. (2018). A facile strategy for preparation of magnetic graphene oxide composites and their potential for environmental adsorption. *Ceramics International, 44*(15), 18571-18577.

M.A. Tadda, A. A., A. Shitu, M. ElSergany, T. Arunkumar, Bipin Jose, M. Abdur Razzaque, N.N. Nik, & Daud1. (2016). A review on activated carbon: process, application and prospects. *Journal of Advanced Civil Engineering Practice and Research, 2*(1), 7.

Ma, J., Guo, Q., Gao, H.-L., & Qin, X. (2015). Synthesis of C60/Graphene Composite as Electrode in Supercapacitors. *Fullerenes, Nanotubes and Carbon Nanostructures, 23*(6), 477-482..

Macías-García, A., García-Sanz-Calcedo, J., Carrasco-Amador, J. P., & Segura-Cruz, R. (2019). Adsorption of Paracetamol in Hospital Wastewater Through Activated Carbon Filters. *Sustainability, 11*(9), 2672.

Madhura Mohan, G., & Rakesh Ravindra, S. (2015). Fullerenes: Chemistry and Its Applications. *Mini-Reviews in Organic Chemistry, 12*(4), 355-366.

Manzoor, K., Ahmad, M., Ahmad, S., & Ikram, S. (2019). Removal of Pb(ii) and Cd(ii) from wastewater using arginine cross-linked chitosan–carboxymethyl cellulose beads as green adsorbent. *RSC Advances, 9*(14), 7890-7902.

Mani Tripathi, S., & Chaurasia, S. (2020). Detection of Chromium in surface and groundwater and its bio-absorption using bio-wastes and vermiculite. *Engineering Science and Technology, an International Journal, 23*(5), 1153-1161.

Marco-Lozar, J. P., Kunowsky, M., Suárez-García, F., Carruthers, J. D., & Linares-Solano, A. (2012). Activated carbon monoliths for gas storage at room temperature. *Energy & Environmental Science, 5*(12), 9833-9842.

Martin, S. a. G. W. (2009). Human Health Effects of Heavy Metals. *Environmental Science and Technology Briefs from Citizens,, 15*, 6.

Mauter, M. S., & Elimelech, M. (2008). Environmental Applications of Carbon-Based Nanomaterials. *Environmental Science & Technology, 42*(16), 5843-5859. =

Melios, C., Giusca, C. E., Panchal, V., & Kazakova, O. (2018). Water on graphene: review of recent progress. *2D Materials, 5*(2), 022001.

Mishra, A. K., & Ramaprabhu, S. (2012). Nanostructured polyaniline decorated graphene sheets for reversible CO2 capture. *Journal of Materials Chemistry, 22*(9), 3708-3712.

MISHRA, M. K. (2016). Fourier Transform Infrared Spectrophotometry Studies of Chromium Trioxide-Phthalic Acid Complexes. *Chemical Science Transactions 5(3), 770-774*.

Mohajeri, A., & Omidvar, A. (2015). Fullerene-based materials for solar cell applications: design of novel acceptors for efficient polymer solar cells – a DFT study. *Physical Chemistry Chemical Physics, 17*(34), 22367-22376.

Mohammad Hadi Dehghani, M. M. T., Anil Kumar Bajpai , Behzad Heibati,Inderjeet Tyagi, Mohammad Asif, Shilpi Agarwal, Vinod Kumar Gupta. (2015). Removal of noxious Cr (VI) ions using single-walled carbon nanotubes and multi-walled carbon nanotubes. *Chemical Engineering Journal, 279*, 8.

Mohammadi, M., Reinicke, B., & Wawrousek, K. (2022). Biosorption and biomagnetic recovery of La3+ by Magnetospirillum magneticum AMB-1 biomass. *Separation and Purification Technology, 303*, 122140.

Mohan, V. B., Lau, K.-t., Hui, D., & Bhattacharyya, D. (2018). Graphene-based materials and their composites: A review on production, applications and product limitations. *Composites Part B: Engineering, 142*, 200-220.

Monisha JAISHANKAR, T. T., Naresh ANBALAGAN, Blessy B. MATHEW , Krishnamurthy N. BEEREGOWDA. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdiscip Toxicol., 7*(2), 12.

Moradi, O., Zare, K., & Yari, M. (2011). Interaction of some heavy metal ions with single walled carbon nanotube. *International Journal of Nano Dimension, 1*(3), 203-220. doi: 10.7508/ijnd.2010.03.004.

Moreno-Castilla, C., Álvarez-Merino, M. A., López-Ramón, M. V., & Rivera-Utrilla, J. (2004). Cadmium Ion Adsorption on Different Carbon Adsorbents from Aqueous Solutions. Effect of Surface Chemistry, Pore Texture, Ionic Strength, and Dissolved Natural Organic Matter. *Langmuir, 20*(19), 8142-8148.

Mousavi, S. M., Hashemi, S. A., Amani, A. M., Esmaeili, H., Ghasemi, Y., Babapoor, A., . . . Arjomand, O. (2018). Pb(II) Removal from Synthetic Wastewater Using Kombucha Scoby and Graphene Oxide/Fe3O4. *Physical Chemistry Research, 6*(4), 759-771.

Moussa, F. (2018). 5 - [60]Fullerene and derivatives for biomedical applications. In R. Narayan (Ed.), *Nanobiomaterials* (pp. 113-136): Woodhead Publishing.

Mukherjee, A., Okolie, J. A., Abdelrasoul, A., Niu, C., & Dalai, A. K. (2019). Review of post-combustion carbon dioxide capture technologies using activated carbon. *Journal of Environmental Sciences, 83*, 46-63.

Mahipal Singh Sankhla, R. K., and Lalit Prasad. (2019). Zinc Impurity in Drinking Water and Its Toxic Effect on Human Health. *Indian Internet Journal of Forensic Medicine & Toxicology, 17*(4), 4.

Murillo Pulgarín, J. A., Alañón Molina, A., Jiménez García, E., & García Gómez, L. (2020). A sensitive resonance Rayleigh scattering sensor for dopamine in urine using upconversion nanoparticles. *Journal of Raman Spectroscopy, 51*(3), 406-413..

Muyssen, B. T., De Schamphelaere, K. A., & Janssen, C. R. (2006). Mechanisms of chronic waterborne Zn toxicity in Daphnia magna. *Aquat Toxicol, 77*(4), 393-401.

Namasivayam, S. K. R., Kumar, S. N., Kamil, T. M., & Ravi, T. (2020). Biopolymer-Mediated Coating Influence on Wastewater Treatment Efficacy of Silver Nanoparticles Synthesized from Fungal Consortium. *National Academy Science Letters*.

Negara, D. N. K. P., Nindhia, T. G. T., Surata, I. W., Hidajat, F., & Sucipta, M. (2020). Textural characteristics of activated carbons derived from tabah bamboo manufactured by using H3PO4 chemical activation. *Materials Today: Proceedings, 22*, 148-155.

Nicholas, A. F., Hussein, M. Z., Zainal, Z., & Khadiran, T. (2018). Palm Kernel Shell Activated Carbon as an Inorganic Framework for Shape-Stabilized Phase Change Material. *Nanomaterials, 8*(9), 689.

Nasir, S., Hussein, M. Z., Zainal, Z., Yusof, N. A., & Mohd Zobir, S. A. (2018). Electrochemical Energy Storage Potentials of Waste Biomass: Oil Palm Leaf- and Palm Kernel Shell-Derived Activated Carbons. *Energies, 11*(12), 3410.

MISHRA, M. K. (2016). Fourier Transform Infrared Spectrophotometry Studies of Chromium Trioxide-Phthalic Acid Complexes. *Chem Sci Trans.*, *5*(3), 5.

Moro, M. K., dos Santos, F. D., Folli, G. S., Romão, W., & Filgueiras, P. R. (2021). A review of chemometrics models to predict crude oil properties from nuclear magnetic resonance and infrared spectroscopy. *Fuel*, *303*, 121283.

Murillo Pulgarín, J. A., Alañón Molina, A., Jiménez García, E., & García Gómez, L. (2020). A sensitive resonance Rayleigh scattering sensor for dopamine in urine using upconversion nanoparticles. *Journal of Raman Spectroscopy, 51*(3), 406-413..

Manzoor, J., Sharma, M., & Wani, K. A. (2018). Heavy metals in vegetables and their impact on the nutrient quality of vegetables: A review. *Journal of Plant Nutrition, 41*(13), 1744-1763.

Mohammad Hadi Dehghani, M. M. T., Anil Kumar Bajpai , Behzad Heibati,Inderjeet Tyagi, Mohammad Asif, Shilpi Agarwal, Vinod Kumar Gupta. (2015). Removal of noxious Cr (VI) ions using single-walled carbon nanotubes and multi-walled carbon nanotubes. *Chemical Engineering Journal, 279*, 8.

Mustapha, S., Shuaib, D. T., Ndamitso, M. M., Etsuyankpa, M. B., Sumaila, A., Mohammed, U. M., & Nasirudeen, M. B. (2019). Adsorption isotherm, kinetic and thermodynamic studies for the removal of Pb(II), Cd(II), Zn(II) and Cu(II) ions from aqueous solutions using Albizia lebbeck pods. *Applied Water Science, 9*(6), 142.

Nakamura, T., Hamasaki, M., Yoshitomi, H., Ishibashi, T., Yoshiyama, C., Maeda, E., Yoshida, H. (2015). Environmental surveillance of poliovirus in sewage water around the introduction period for inactivated polio vaccine in Japan. *Applied and environmental microbiology, 81*(5), 1859-1864.

Nasir, S., Hussein, M. Z., Zainal, Z., Yusof, N. A., & Mohd Zobir, S. A. (2018). Electrochemical Energy Storage Potentials of Waste Biomass: Oil Palm Leaf- and Palm Kernel Shell-Derived Activated Carbons. *Energies, 11*(12), 3410.

Nicholas, A. F., Hussein, M. Z., Zainal, Z., & Khadiran, T. (2018). Palm Kernel Shell Activated Carbon as an Inorganic Framework for Shape-Stabilized Phase Change Material. *Nanomaterials, 8*(9), 689.

Ntim, S. A., & Mitra, S. (2012). Adsorption of arsenic on multiwall carbon nanotube-zirconia nanohybrid for potential drinking water purification. *Journal of colloid and interface science, 375*(1), 154-159.

Oliveira, J. R. P., Rodrigues, R. O., Barros, L., Ferreira, I. C. F. R., Marchesi, L. F., Koneracka, M., . . . Gomes, H. T. (2018). Carbon-Based Magnetic Nanocarrier for Controlled Drug Release: A Green Synthesis Approach. *C — Journal of Carbon Research, 5*(1), 1.

Olvera, O. G., & Domanski, D. F. R. (2019). Effect of activated carbon on the thiosulfate leaching of gold. *Hydrometallurgy, 188*, 47-53.

Pan, G., Wang, L., Song, S., Xu, Z., Fu, D., & Zhang, G. (2018). Preparation of Modified Graphene Oxide Nanomaterials for Water and Wastewater Treatment. *IOP Conference Series: Earth and Environmental Science, 170*, 032074.

Park, H.-A., Liu, S., Salvador, P. A., Rohrer, G. S., & Islam, M. F. (2016). High visible-light photochemical activity of titania decorated on single-wall carbon nanotube aerogels. *RSC Advances, 6*(27), 22285-22294.

Partha, R., & Conyers, J. L. (2009). Biomedical applications of functionalized fullerene-based nanomaterials. *Int J Nanomedicine, 4*, 261-275.

Parvin, A., & Hoque, S. (2016). Removal of Pb and Zn from industrial effluent using humic acid. . *Bangladesh Journal of Scientific and Industrial Research, 51*(4), 5.

Plata-Gryl, M., Momotko, M., Makowiec, S., & Boczkaj, G. (2020). Application of cyanated asphaltenes in gas-phase adsorption processes for removal of volatile organic compounds. *Chemical Papers, 74*(3), 995-1008.

Petuhov, O., Lupascu, T., Behunová, D., Povar, I., Mitina, T., & Rusu, M. (2019). Microbiological Properties of Microwave-Activated Carbons Impregnated with Enoxil and Nanoparticles of Ag and Se. *C — Journal of Carbon Research, 5*(2), 31.

Pickering, K. D. (2005). *Photochenistry and eenvironmental applications of water soluble fullerene compounds.* (PhD), Rice University, Houstan texas.

Pilehvar, S., & De Wael, K. (2015). Recent Advances in Electrochemical Biosensors Based on Fullerene-C60 Nano-Structured Platforms. *Biosensors, 5*(4), 712-735.

Poorva Mehndiratta, A. J., Sudha Srivastava & Nidhi Gupta. (2013). Environmental Pollution and Nanotechnology. *Environment and Pollution, 2*(2), 10.

Poulsen, S. S., Knudsen, K. B., Jackson, P., Weydahl, I. E. K., Saber, A. T., Wallin, H., & Vogel, U. (2017). Multi-walled carbon nanotube-physicochemical properties predict the systemic acute phase response following pulmonary exposure in mice. *PLoS ONE, 12*(4), e0174167.

Pyrzyńska, K., & Bystrzejewski, M. (2010). Comparative study of heavy metal ions sorption onto activated carbon, carbon nanotubes, and carbon-encapsulated magnetic nanoparticles. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 362*(1), 102-109.

Poorva Mehndiratta, A. J., Sudha Srivastava & Nidhi Gupta. (2013). Environmental Pollution and Nanotechnology. *Environment and Pollution, 2*(2), 10.

Phan, V. T. H., Quirico, E., Beck, P., Le Brech, Y., Jovanovic, L., Le Guillou, C., . . . Raya, J. (2021). Infrared spectroscopy quantification of functional carbon groups in kerogens and coals: A calibration procedure. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 259*, 119853.

Pan, X.-D., Wu, P.-G., & Jiang, X.-G. (2016). Levels and potential health risk of heavy metals in marketed vegetables in Zhejiang, China. *Scientific Reports, 6*(1), 20317.

PEGO, M. F. F., BIANCHI, M. L., CARVALHO, J. A., & VEIGA, T. R. L. A. (2019). Surface modification of activated carbon by corona treatment. *Anais da Academia Brasileira de Ciências, 91*.

Peng, E., Todorova, N., & Yarovsky, I. (2018). Effects of Size and Functionalization on the Structure and Properties of Graphene Oxide Nanoflakes: An in Silico Investigation. *ACS Omega, 3*(9), 11497-11503.

Qin, F.-L., Wang, X.-C., Ding, S.-R., Li, G.-S., & Hou, Z.-C. (2021). Prediction of Peking duck intramuscle fat content by near-infrared spectroscopy. *Poultry Science, 100*(8), 101281.

Redman, Z. C., Tran, K. H., Parikh, S. J., & Tjeerdema, R. S. (2019). Influence of pH and Divalent Metals Relevant to California Rice Fields on the Hydroxide-Mediated Hydrolysis of the Insecticide Chlorantraniliprole. *Journal of Agricultural and Food Chemistry, 67*(45), 12402-12407.

Rehman, K., Fatima, F., Waheed, I., & Akash, M. S. H. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. *J Cell Biochem, 119*(1), 157-184..

Renu, M. A., Singh, K., Upadhyaya, S., & Dohare, R. K. (2017). Removal of heavy metals from wastewater using modified agricultural adsorbents. *Materials Today: Proceedings, 4*(9), 10534-10538.

Robert, C., Jessep, W., Sutton, J. J., Hicks, T. M., Loeffen, M., Farouk, M., . . . Gordon, K. C. (2021). Evaluating low- mid- and high-level fusion strategies for combining Raman and infrared spectroscopy for quality assessment of red meat. *Food Chemistry, 361*, 130154.

Redman, Z. C., Tran, K. H., Parikh, S. J., & Tjeerdema, R. S. (2019). Influence of pH and Divalent Metals Relevant to California Rice Fields on the Hydroxide-Mediated Hydrolysis of the Insecticide Chlorantraniliprole. *Journal of Agricultural and Food Chemistry, 67*(45), 12402-12407.

Ruiz-Rosas, R., García-Mateos, F. J., Gutiérrez, M. d. C., Rodríguez-Mirasol, J., & Cordero, T. (2019). About the Role of Porosity and Surface Chemistry of Phosphorus-Containing Activated Carbons in the Removal of Micropollutants. *Frontiers in Materials, 6*(134).

Rahman, M. M., Sime, S.A., Hossain, M.A. (2017). Removal of Pollutants from Water by Using Single-Walled Carbon Nanotubes (SWCNTs) and Multi-walled Carbon Nanotubes (MWCNTs). *Arab J Sci Eng, 42*.

Rao, G. P., Lu, C., & Su, F. (2007). Sorption of divalent metal ions from aqueous solution by carbon nanotubes: A review. *Separation and Purification Technology, 58*(1), 224-231.

Raphey, V. R., Henna, T. K., Nivitha, K. P., Mufeedha, P., Sabu, C., & Pramod, K. (2019). Advanced biomedical applications of carbon nanotube. *Materials Science and Engineering: C, 100*, 616-630.

Ravelli, D., Dondi, D., Fagnoni, M., & Albini, A. (2009). Photocatalysis. A multi-faceted concept for green chemistry. *Chemical Society Reviews, 38*(7), 1999-2011.

Ray, S. C. (2015a). Chapter 1 - Application and Uses of Graphene. In S. C. Ray (Ed.), *Applications of Graphene and Graphene-Oxide Based Nanomaterials* (pp. 1-38). Oxford: William Andrew Publishing.

Robati, D. (2013). Pseudo-second-order kinetic equations for modeling adsorption systems for removal of lead ions using multi-walled carbon nanotube. . *J. Nanostruct. Chem., 3*(1).

Romantsova, I. V., Burakov, A. E., Kucherova, A. E., Neskoromnaya, E. A., Babkin, A. V., & Tkachev, A. G. (2016). Kinetics of liquid-phase adsorption of organic dye on activated carbons. *Protection of Metals and Physical Chemistry of Surfaces, 52*(5), 782-785.

Rommozzi, E., Zannotti, M., Giovannetti, R., D'Amato, C. A., Ferraro, S., Minicucci, M., . . . Di Cicco, A. (2018). Reduced Graphene Oxide/TiO2 Nanocomposite: From Synthesis to Characterization for Efficient Visible Light Photocatalytic Applications. *Catalysts, 8*(12), 598.

Renu, M. A., Singh, K., Upadhyaya, S., & Dohare, R. K. (2017). Removal of heavy metals from wastewater using modified agricultural adsorbents. *Materials Today: Proceedings, 4*(9), 10534-10538.

Özsin, G., Kılıç, M., Apaydın-Varol, E., & Pütün, A. E. (2019). Chemically activated carbon production from agricultural waste of chickpea and its application for heavy metal adsorption: equilibrium, kinetic, and thermodynamic studies. *Applied Water Science, 9*(3), 56..

Rauti, R., Musto, M., Bosi, S., Prato, M., & Ballerini, L. (2019). Properties and behavior of carbon nanomaterials when interfacing neuronal cells: How far have we come? *Carbon, 143*, 430-446.

Redman, Z. C., Tran, K. H., Parikh, S. J., & Tjeerdema, R. S. (2019). Influence of pH and Divalent Metals Relevant to California Rice Fields on the Hydroxide-Mediated Hydrolysis of the Insecticide Chlorantraniliprole. *Journal of Agricultural and Food Chemistry, 67*(45), 12402-12407.

Saba, S. (2018). Biosorption of Heavy Metals. In D. Jan & V. Branislav (Eds.), *Biosorption* (pp. Ch. 2). Rijeka: IntechOpen.

Shibata, M., Varman, M., Tono, Y., Miyafuji, H., & Saka, S. (2008). Characterization in Chemical Composition of the Oil Palm (Elaeis guineensis). *Journal of the Japan Institute of Energy, 87*(5), 383-388.

Simonin, J.-P. (2016). On the comparison of pseudo-first order and pseudo-second order rate laws in the modeling of adsorption kinetics. *Chemical Engineering Journal $V 300*, 254-263.

Shi, X., Ding, Z., Wang, C., Song, S., & Zhou, X. (2020). Effect of different cellulose polymers on the crystal growth of celecoxib polymorphs. *Journal of Crystal Growth, 539*, 125638..

Solomons, F. S. s. (2018). *Organic Chemistry* (11 ed.). United States of America 10 9 8 7 6 5 4 3 2 1.

Saifullah, B., El Zowalaty, M. E., Arulselvan, P., Fakurazi, S., Webster, T. J., Geilich, B. M., & Hussein, M. Z. (2014). Antimycobacterial, antimicrobial, and biocompatibility properties of para-aminosalicylic acid with zinc layered hydroxide and Zn/Al layered double hydroxide nanocomposites. *Drug Des Devel Ther, 8*, 1029-1036.

Sardans, J., Montes, F., & Peñuelas, J. (2011). Electrothermal Atomic Absorption Spectrometry to Determine As, Cd, Cr, Cu, Hg, and Pb in Soils and Sediments: A Review and Perspectives. *Soil and Sediment Contamination: An International Journal, 20*(4), 447-491.

Sud, D., Mahajan, G., & Kaur, M. P. (2008). Agricultural waste material as potential adsorbent for sequestering heavy metal ions from aqueous solutions - a review. *Bioresour Technol, 99*(14), 6017-6027.

S. Mazzuoli, A. T., F. Bartolini, S. Loiselle & C. Rossi (2004). *Applications of humic acids in the treatment of heavy metal contamination* Italy: WIT Press.

Saifullah, B., Buskaran, K., Shaikh, R. B., Barahuie, F., Fakurazi, S., Mohd Moklas, M. A., & Hussein, M. Z. (2018). Graphene Oxide–PEG–Protocatechuic Acid Nanocomposite Formulation with Improved Anticancer Properties. *Nanomaterials, 8*(10), 820.

Saifullah, B., Chrzastek, A., Maitra, A., Naeemullah, B., Fakurazi, S., Bhakta, S., & Hussein, M. Z. (2017). Novel Anti-Tuberculosis Nanodelivery Formulation of Ethambutol with Graphene Oxide. *Molecules, 22*(10).

Samonin, V. V., Nikonova, V. Y., & Podvyaznikov, M. L. (2008). Sorption properties of fullerene-modified activated carbon with respect to metal ions. *Protection of Metals, 44*(2), 190-192.

Samonin, V. V., Nikonova, V. Y., & Podvyaznikov, M. L. (2014). Carbon adsorbents on the basis of the hydrolytic lignin modified with fullerenes in producing. *Russian Journal of Applied Chemistry, 87*(2), 190-193. doi: 10.1134/s1070427214020116.

Sardans, J., Montes, F., & Peñuelas, J. (2011). Electrothermal Atomic Absorption Spectrometry to Determine As, Cd, Cr, Cu, Hg, and Pb in Soils and Sediments: A Review and Perspectives. *Soil and Sediment Contamination: An International Journal, 20*(4), 447-491.

Sharma, P. a. D., R.S. (2005). Lead Toxicity in Plants. *Brazilian Journal of Plant Physiology, 17*, 18..

Shen, Y., Reparaz, J. S., Wagner, M. R., Hoffmann, A., Thomsen, C., Lee, J.-O., . . . Nakanishi, T. (2011). Assembly of carbon nanotubes and alkylated fullerenes: nanocarbon hybrid towards photovoltaic applications. *Chemical Science, 2*(11), 2243-2250..

Shweta Gupta, D. B. C. N. M. (2015). Metal Removal Studies by Composite Membrane of Polysulfone and Functionalized Single-Walled Carbon Nanotubes. *Separation Science and Technology 50*(3), 9.

Singh, R. P. (2011). Prospects of Nanobiomaterials for Biosensing. *International Journal of Electrochemistry, 2011*, 30..

Stafiej, A., & Pyrzynska, K. (2007). Adsorption of heavy metal ions with carbon nanotubes. *Separation and Purification Technology, 58*(1), 49-52.

Sardans, J., Montes, F., & Peñuelas, J. (2011). Electrothermal Atomic Absorption Spectrometry to Determine As, Cd, Cr, Cu, Hg, and Pb in Soils and Sediments: A Review and Perspectives. *Soil and Sediment Contamination: An International Journal, 20*(4), 447-491.

Sardans, J., Montes, F., & Peñuelas, J. (2011). Electrothermal Atomic Absorption Spectrometry to Determine As, Cd, Cr, Cu, Hg, and Pb in Soils and Sediments: A Review and Perspectives. *Soil and Sediment Contamination: An International Journal, 20*(4), 447-491..

Solomons, F.S.s., *Organic Chemistry* 11 ed, ed. J. Yee. 2018, United States of America 10, 1139.

Sud, D., Mahajan, G., & Kaur, M. P. (2008). Agricultural waste material as potential adsorbent for sequestering heavy metal ions from aqueous solutions - a review. *Bioresour Technol, 99*(14), 6017-6027.

Sun, H., Zhan, J., Chen, L., & Zhao, Y. (2023). Preparation of CTS/PAMAM/SA/Ca2+ hydrogel and its adsorption performance for heavy metal ions. *Applied Surface Science, 607*, 155135.

Tan, C. 2012). Energy and environmental applications of carbon nanotubes. *Environmental Chemistry Letters, 10*(3), 9.

Tabish, T. A., Memon, F. A., Gomez, D. E., Horsell, D. W., & Zhang, S. (2018). A facile synthesis of porous graphene for efficient water and wastewater treatment. *Scientific reports, 8*(1), 1817.

Tlili, M. B. a. H. (2018). Removal of heavy metals from wastewater using infiltration-percolation process and adsorption on activated carbon. *International Journal of Environmental Science and Technology*.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. *Exp Suppl, 101*, 133-164.

Treto-Suárez, M. A., Prieto-García, J. O., Mollineda-Trujillo, Á., Lamazares, E., Hidalgo-Rosa, Y., & Mena-Ulecia, K. (2020). Kinetic study of removal heavy metal from aqueous solution using the synthetic aluminum silicate. *Scientific Reports, 10*(1), 10836.

Tan, C. M., Baudot, C., Han, Y., & Jing, H. (2012). Applications of multi-walled carbon nanotube in electronic packaging. *Nanoscale research letters, 7*(1), 183-183.

Tan, J. M., Arulselvan, P., Fakurazi, S., Ithnin, H., & Hussein, M. Z. (2014). A Review on Characterizations and Biocompatibility of Functionalized Carbon Nanotubes in Drug Delivery Design. *Journal of Nanomaterials, 2014*, 20.

Tang, W.-W., Zeng, G.-M., Gong, J.-L., Liang, J., Xu, P., Zhang, C., & Huang, B.-B. (2014). Impact of humic/fulvic acid on the removal of heavy metals from aqueous solutions using nanomaterials: A review. *Science of The Total Environment, 468-469*, 1014-1027.

Tang, Y., Wang, J., & Gao, N. (2010). Characteristics and model studies for fluoride and arsenic adsorption on goethite. *Journal of Environmental Sciences, 22*(11), 1689-1694.

Thakur, S., Govender, P. P., Mamo, M. A., Tamulevicius, S., Mishra, Y. K., & Thakur, V. K. (2017). Progress in lignin hydrogels and nanocomposites for water purification: Future perspectives. *Vacuum, 146*, 342-355.

Tumolo, M., Ancona, V., & De Paola, D. (2020). Chromium Pollution in European Water, Sources, Health Risk, and Remediation Strategies: An Overview. *17*(15).

Udayakantha, K. S. M., de Silva, R. M., de Silva, K. M. N., & Hettiarachchi, C. (2015). Biocompatible nano hydroxyapatite – curcumin bi-coated antibacterial activated carbon for water purification. *RSC Advances, 5*(79), 64696-64703.

Uğurlu, M., Kula, I., Karaoğlu, M.H., Arslan, Y. (2009). Removal of Ni (II) ions from aqueous solutions using activated carbon prepared from olive stone by ZnCl2 activation. *Environ. Prog. Sustain., 28*(4), 11.

Velma V, V. S., Tchounwou PB. (2009). Ecotoxicology of hexavalent chromium in freshwater fish: a critical review. . *Rev Environ Health, 4*(2), 16.

Vidu, R., Rahman, M., Mahmoudi, M., Enachescu, M., Poteca, T. D., & Opris, I. (2014). Nanostructures: a platform for brain repair and augmentation. *Front Syst Neurosci, 8*(91).

Vidyaev, D. G., Savostikov, D. V., Boretsky, E. A., & Verkhorubov, D. L. . (2016). Hydrogen sorption by carbon nanostructured materials. . *Jr. of Industrial pollution control, 32*, 4.

Vilela, D., Parmar, J., Zeng, Y., Zhao, Y., & Sánchez, S. (2016). Graphene-Based Microbots for Toxic Heavy Metal Removal and Recovery from Water. *Nano Letters, 16*(4), 2860-2866.

Vinod Kumar Gupta, I. T., Hamidreza Sadegh, Ramin Shahryari-Ghoshekandi, Abdel Salam Hamdy Makhlouf and Behnam Maazinejad (2015). Nanoparticles as Adsorbent; A Positive Approach for Removal of Noxious Metal Ions: A review. *Science, Technology and Development, 34*, 20.

Waalkes M, W. Z., Rodriguez E. Cadmium. In: Sullivan JB Jr. Krieger GR. . (2001). *Clinical Environmental Health and Toxic Exposures.* (Vol. 2nd Edition.): Lippincott Williams & Wilkins.

Wang, Z., Feng, X., Liu, J., Lu, M., & Li, M. (2020). Functional groups prediction from infrared spectra based on computer-assist approaches. *Microchemical Journal, 159*, 105395..

Wang, L., Shi, C., Pan, L., Zhang, X., & Zou, J.-J. (2020). Rational design, synthesis, adsorption principles and applications of metal oxide adsorbents: a review. *Nanoscale, 12*(8), 4790-4815.

Wei, J., Duan, M., Li, Y., Nwankwegu, A. S., Ji, Y., & Zhang, J. (2019). Concentration and pollution assessment of heavy metals within surface sediments of the Raohe Basin, China. *Scientific Reports, 9*(1), 13100.

WHO. (2004). Guidelines for drinking-water quality. . Sixty-fi rst meeting, Rome, 10–19 June 2003. : Joint FAO/WHO Expert Committee on Food Additives.

WHO. (2017). Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum Quality (pp. 631).

Wong, S., Ngadi, N., Inuwa, I. M., & Hassan, O. (2018). Recent advances in applications of activated carbon from biowaste for wastewater treatment: A short review. *Journal of Cleaner Production, 175*, 361-375.

World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). (2017). Progress on Drinking Water, Sanitation and Hygiene. In A. Grojec (Ed.). Switzerland.

Wu, Y., Pang, H., Liu, Y., Wang, X., Yu, S., Fu, D., Wang, X. (2019). Environmental remediation of heavy metal ions by novel-nanomaterials: A review. *Environmental Pollution, 246*, 608-620. .

Wu, Y., Pang, H., Liu, Y., Wang, X., Yu, S., Fu, D., . . . Wang, X. (2019). Environmental remediation of heavy metal ions by novel-nanomaterials: A review. *Environmental Pollution, 246*, 608-620.

World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). (2017). Progress on Drinking Water, Sanitation and Hygiene. In A. Grojec (Ed.). Switzerland.

Xia, K., Zhan, H., & Gu, Y. (2017). Graphene and Carbon Nanotube Hybrid Structure: A Review. *Procedia IUTAM, 21*, 94-101. doi: https://doi.org/10.1016/j.piutam.2017.03.042.

Xiangtao Wang, Y. G., Li Yang, Meihua Han, Jing Zhao and Xiaoliang Cheng. (2012). Nanomaterials as Sorbents to Remove Heavy Metal Ions in Wastewater Treatment. *J Environ Anal Toxicol 2012, 2:154, 2*.

Xu, Z., Liu, H., Niu, J., Zhou, Y., Wang, C., & Wang, Y. (2017). Hydroxyl multi-walled carbon nanotube-modified nanocrystalline PbO2 anode for removal of pyridine from wastewater. *Journal of Hazardous Materials, 327*, 144-152.

Yakout, S. M., & Sharaf El-Deen, G. (2016). Characterization of activated carbon prepared by phosphoric acid activation of olive stones. *Arabian Journal of Chemistry, 9*, S1155-S1162. doi: https://doi.org/10.1016/j.arabjc.2011.12.002.

Yamada, K., Kim, C.-T., Kim, J.-H., Chung, J.-H., Lee, H. G., & Jun, S. (2014). Single Walled Carbon Nanotube-Based Junction Biosensor for Detection of Escherichia coli. *PLoS ONE, 9*(9), e105767..

Yan, H., Li, H., Tao, X., Li, K., Yang, H., Li, A., . . . Cheng, R. (2014). Rapid Removal and Separation of Iron(II) and Manganese(II) from Micropolluted Water Using Magnetic Graphene Oxide. *ACS Applied Materials & Interfaces, 6*(12), 9871-9880. doi: 10.1021/am502377n.

Yang, S., Li, J., Shao, D., Hu, J., & Wang, X. (2009). Adsorption of Ni(II) on oxidized multi-walled carbon nanotubes: effect of contact time, pH, foreign ions and PAA. *J Hazard Mater, 166*(1), 109-116.

Yang, X., Zhou, T., Ren, B., Hursthouse, A., & Zhang, Y. (2018). Removal of Mn (II) by Sodium Alginate/Graphene Oxide Composite Double-Network Hydrogel Beads from Aqueous Solutions. *Scientific reports, 8*(1), 10717-10717.

Yang, Z.-z., Zhang, C., Zeng, G.-m., Tan, X.-f., Wang, H., Huang, D.-l., . . . Nie, K. (2020). Design and engineering of layered double hydroxide based catalysts for water depollution by advanced oxidation processes: a review. *Journal of Materials Chemistry A, 8*(8), 4141-4173.

Yang, X., Zhou, T., Ren, B., Hursthouse, A., & Zhang, Y. (2018). Removal of Mn (II) by Sodium Alginate/Graphene Oxide Composite Double-Network Hydrogel Beads from Aqueous Solutions. *Scientific reports, 8*(1), 10717-10717.

Yáñez-Sedeño, P., Campuzano, S., & Pingarrón, J. M. (2017). Fullerenes in Electrochemical Catalytic and Affinity Biosensing: A Review. *C, 3*(3), 21.

Yang, S., Li, J., Shao, D., Hu, J., & Wang, X. (2009). Adsorption of Ni(II) on oxidized multi-walled carbon nanotubes: effect of contact time, pH, foreign ions and PAA. *J Hazard Mater, 166*(1), 109-116.

Yang, X., Zhou, T., Ren, B., Hursthouse, A., & Zhang, Y. (2018). Removal of Mn (II) by Sodium Alginate/Graphene Oxide Composite Double-Network Hydrogel Beads from Aqueous Solutions. *Scientific reports, 8*(1), 10717-10717.

Yu, Q., Zhao, H., Zhao, H., Sun, S., Ji, X., Li, M., & Wang, Y. (2019). Preparation of tobacco-stem activated carbon from using response surface methodology and its application for water vapor adsorption in solar drying system. *Solar Energy, 177*, 324-336.

Yu, X. Y., Luo, T., Zhang, Y. X., Jia, Y., Zhu, B. J., Fu, X. C., . . . Huang, X. J. (2011). Adsorption of lead(II) on O(2)-plasma-oxidized multiwalled carbon nanotubes: thermodynamics, kinetics, and desorption. *ACS Appl Mater Interfaces, 3*(7), 2585-2593.

Yuan, J., & Mohamadi, A. (2021). Study the adsorption process of 5-Fluorouracil drug on the pristine and doped graphdiyne nanosheet. *Journal of Molecular Modeling, 27*(2), 32.

Zhong, Q., & Jin, M. (2009). Nanoscalar Structures of Spray-Dried Zein Microcapsules and in Vitro Release Kinetics of the Encapsulated Lysozyme As Affected by Formulations. *Journal of Agricultural and Food Chemistry, 57*(9), 3886-3894.

Zaytseva, O., & Neumann, G. (2016). Carbon nanomaterials: production, impact on plant development, agricultural and environmental applications. *Chemical and Biological Technologies in Agriculture, 3*(1), 17. .

Zięzio, M., Charmas, B., Jedynak, K., Hawryluk, M., & Kucio, K. (2020). Preparation and characterization of activated carbons obtained from the waste materials impregnated with phosphoric acid(V). *Applied Nanoscience, 10*(12), 4703-4716.

Zhang, C.-Z., Chen, B., Bai, Y., & Xie, J. (2018). A new functionalized reduced graphene oxide adsorbent for removing heavy metal ions in water via coordination and ion exchange. *Separation Science and Technology, 53*(18), 2896-2905.

Zhong, Q., & Jin, M. (2009). Nanoscalar Structures of Spray-Dried Zein Microcapsules and in Vitro Release Kinetics of the Encapsulated Lysozyme As Affected by Formulations. *Journal of Agricultural and Food Chemistry, 57*(9), 3886-3894.

Zazouli, M. A., Yousefi, Z., Yazdani Cherati, J., Tabarinia, H., Tabarinia, F., & Akbari Adergani, B. (2014). Evaluation of L-Cysteine Functionalized Single-Walled Carbon Nanotubes On Mercury Removal from Aqueous Solutions. *Journal of Mazandaran University of Medical Sciences, 24*(111), 10-21.

Zeng, G., Chen, T., Huang, L., Liu, M., Jiang, R., Wan, Q., . . . Wei, Y. (2018). Surface modification and drug delivery applications of MoS2 nanosheets with polymers through the combination of mussel inspired chemistry and SET-LRP. *Journal of the Taiwan Institute of Chemical Engineers, 82*, 205-213.

Zeng, G., Liu, X., Liu, M., Huang, Q., Xu, D., Wan, Q., . . . Wei, Y. (2016). Facile preparation of carbon nanotubes based carboxymethyl chitosan nanocomposites through combination of mussel inspired chemistry and Michael addition reaction: Characterization and improved Cu2+ removal capability. *Journal of the Taiwan Institute of Chemical Engineers, 68*, 446-454. \

Zeng, X., Xia, J., Wang, Z., & Li, W. (2015). Removal of iron and manganese in steel industry drainage by biological activated carbon. *Desalination and Water Treatment, 56*(9), 2543-2550.

Zhang, B. T., Zheng, X., Li, H. F., & Lin, J. M. (2013). Application of carbon-based nanomaterials in sample preparation: a review. *Anal Chim Acta, 784*, 1-17.

Zhang, C.-Z., Chen, B., Bai, Y., & Xie, J. (2018). A new functionalized reduced graphene oxide adsorbent for removing heavy metal ions in water via coordination and ion exchange. *Separation Science and Technology, 53*(18), 2896-2905.

Zhang, X., Huang, Q., Deng, F., Huang, H., Wan, Q., Liu, M., & Wei, Y. (2017). Mussel-inspired fabrication of functional materials and their environmental applications: Progress and prospects. *Applied Materials Today, 7*, 222-238.

Zhang, Y., Chi, Y., Zhao, C., Liu, Y., Zhao, Y., Jiang, L., & Song, Y. (2018). CO2 Adsorption Behavior of Graphite Oxide Modified with Tetraethylenepentamine. *Journal of Chemical & Engineering Data, 63*(1), 202-207.

Zhao, J., Yang, L., Li, F., Yu, R., & Jin, C. (2009). Structural evolution in the graphitization process of activated carbon by high-pressure sintering. *Carbon, 47*(3), 744-751.

Zhao, X., Jia, Q., Song, N., Zhou, W., & Li, Y. (2010). Adsorption of Pb(II) from an Aqueous Solution by Titanium Dioxide/Carbon Nanotube Nanocomposites: Kinetics, Thermodynamics, and Isotherms. *Journal of Chemical & Engineering Data, 55*(10), 4428-4433.

Zhong, Q., & Jin, M. (2009). Nanoscalar Structures of Spray-Dried Zein Microcapsules and in Vitro Release Kinetics of the Encapsulated Lysozyme As Affected by Formulations. *Journal of Agricultural and Food Chemistry, 57*(9), 3886-3894.

Zhao, Y., Ding, H., & Zhong, Q. (2012). Preparation and characterization of aminated graphite oxide for CO2 capture. *Applied Surface Science*, *258*(10), 4301-4307. \

Zheng, S., Hao, L., Zhang, L., Wang, K., Zheng, W., Wang, X., . . . Zhang, L. (2018). Tea Polyphenols Functionalized and Reduced Graphene Oxide-ZnO Composites for Selective Pb2+ Removal and Enhanced Antibacterial Activity. *Journal of Biomedical Nanotechnology*, *14*(7), 1263-1276.

Zou, J.-P., Chen, Y., Zhu, M., Wang, D., Luo, X.-B., & Luo, S.-L. (2019). 2 - Semiconductor-Based Nanocomposites for Photodegradation of Organic Pollutants. In X. Luo & F. Deng (Eds.), *Nanomaterials for the Removal of Pollutants and Resource Reutilization* (pp. 25-58): Elsevier.

Zeng, G., Chen, T., Huang, L., Liu, M., Jiang, R., Wan, Q., Wei, Y. (2018). Surface modification and drug delivery applications of MoS2 nanosheets with polymers through the combination of mussel inspired chemistry and SET-LRP. *Journal of the Taiwan Institute of Chemical Engineers*, *82*, 205-213.

Zeng, G., Liu, X., Liu, M., Huang, Q., Xu, D., Wan,. Wei, Y. (2016). Facile preparation of carbon nanotubes based carboxymethyl chitosan nanocomposites through combination of mussel inspired chemistry and Michael addition reaction: Characterization and improved Cu2+ removal capability. *Journal of the Taiwan Institute of Chemical Engineers*, *68*, 446-454.

Zhang, X., Huang, Q., Deng, F., Huang, H., Wan, Q., Liu, M., & Wei, Y. (2017). Mussel-inspired fabrication of functional materials and their environmental applications: Progress and prospects. *Applied Materials Today*, *7*, 222-238.