SYNTHESIS OF POLYSULFIDE ADSORBENT FROM WASTE COOKING PALM OIL FOR THE REMOVAL OF IRON (III)

ABDULLAH NAYEEM

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and, in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

_____

(Supervisor's Signature)

Full Name : Dr. Jun Haslinda Binti Haji Shariffuddin

Position : Senior Lecturer

Date : 16th November, 2022

_____

(Co-supervisor's Signature)

Full Name : Dr. Mohd Faizal Bin Ali

Position : Senior Lecturer

Date : 16th November, 2022

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institution.

_____

(Student's Signature)

Full Name : ABDULLAH NAYEEM

ID Number : MKC20003

Date : 16th November, 2022

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ABSTRAK

Sulfur unsur dan minyak sawit masak sisa (WCO) masing-masing merupakan hasil sampingan industri yang banyak daripada industri petrokimia dan pemprosesan makanan. WCO telah berjaya digunakan sebagai penghubung silang untuk menyediakan polimer kandungan sulfur tinggi melalui pemvulkanan songsang untuk penyingkiran ion ferik (Fe^{3+}) dalam air sisa. Dalam kerja semasa, WCO telah dicirikan menggunakan GC-MS, FTIR, dan TGA untuk menilai kebolehlaksanaan untuk digunakan sebagai penyambung silang dalam pemvulkanan songsang. Polisulfida yang dihasilkan telah dianalisis berdasarkan parameter tindak balas yang berbeza termasuk sulfur kepada nisbah silang silang WCO, suhu, masa, dan penggunaan NaCl oleh FTIR, TGA, XRD, SEM-EDX, dan BET. Proses penjerapan dikaji dengan mempelbagaikan pH, kepekatan awal Fe^{3+}, dan dos dengan kajian isoterma dan kinetik yang sesuai. Ikatan berfungsi yang diperlukan dan ketidaktepuan WCO telah disahkan oleh FTIR dan GC-MS, dan kestabilan pada suhu yang lebih tinggi telah disahkan menggunakan TGA. Polisulfida telah disintesis di bawah kacau (500 rpm) WCO dengan unsur sulfur pada tiga suhu berbeza (195 ℃, 190 ℃, dan 185 ℃) dengan tiga nisbah silang silang (70, 60, dan 50 wt% sulfur). Dua set masa tindak balas yang berbeza; 45 min dan 60 min telah digunakan untuk sintesis polisulfida. Sifat fizikokimia polisulfida yang dihasilkan telah ditentukan dan kestabilan terma dianalisis. Spektrum FTIR termasuk pecahan C=C dan pembentukan ikatan C–S mengesahkan perubahan kumpulan berfungsi antara WCO dan polimer yang dihasilkan. Kesan trigliserida tepu dan tak tepu WCO jelas kelihatan dalam mikrograf SEM. Polisulfida dengan nisbah suapan sulfur 70 wt % menunjukkan luas permukaan yang lebih baik. TGA dan DTG menunjukkan bahawa sifat terma yang lebih baik dan polisulfida yang stabil boleh diperoleh daripada jumlah kandungan sulfur yang lebih tinggi. Keadaan optimum lain untuk pemvulkanan songsang juga direkodkan, seperti 60 minit masa tindak balas dan 195 ℃. Permukaan diubah suai menggunakan NaCl sebagai porogen untuk menambah luas permukaan. Keputusan BET mengesahkan peningkatan luas permukaan polisulfida berliang yang disediakan menggunakan NaCl. Prestasi penyingkiran dinilai dengan mengkaji kesan parameter termasuk keliangan, pH larutan, kepekatan awal Fe^{3+}, dan jumlah dos polisulfida. Penyingkiran tertinggi dicatatkan untuk polisulfida berliang. pH berasid (pH=3) adalah baik untuk penyingkiran Fe^{3+}. Dos optimum ialah 20 mg/100 mL. Isoterma penyingkiran telah dikaji dan dipasang paling baik untuk isoterma Freundlich. Kajian kinetik proses penyingkiran telah sesuai dengan baik dalam model kinetik pseudo kedua linear. Disimpulkan bahawa polisulfida tervulkan songsang boleh digunakan dengan jayanya untuk mengurangkan Fe^{3+} dalam air sisa dan mengurangkan ancaman alam sekitar bagi WCO yang berlebihan.

ABSTRACT

Elemental sulfur and waste cooking palm oil (WCO) are abundant industrial by-products from the petrochemical and food processing industries, respectively. WCO has been successfully used as a crosslinker to prepare a high-sulfur-content polymer through inverse vulcanization for the removal of ferric ions (Fe^{3+}) in wastewater. In the current work, WCO has been characterized using GC-MS, FTIR, and TGA to assess the feasibility to be used as a crosslinker in inverse vulcanization. The produced polysulfides were analyzed based on the different reaction parameters including sulfur to WCO crosslinking ratio, temperature, time, and the application of NaCl by FTIR, TGA, XRD, SEM-EDX, and BET. The adsorption process was studied by varying pH, initial Fe^{3+} concentration, and dosage with suitable isothermal and kinetic studies. The required functional bonds and unsaturation of WCO were confirmed by FTIR and GC-MS, and the stability at higher temperatures was confirmed using TGA. Polysulfides were synthesized under stirring (500 rpm) of WCO with elemental sulfur at three different temperatures (195℃, 190℃, and 185℃) with three crosslinking ratios (70, 60, and 50 wt% sulfur). Two different sets of reaction time; 45 min and 60 min have been used for polysulfide synthesis. The physicochemical properties of the produced polysulfides were determined and the thermal stability was analyzed. The FTIR spectra including the breakdown of C=C and formation of C–S bond confirmed the change of functional groups between WCO and produced polymer. The effect of saturated and unsaturated triglycerides of WCO is clearly visible in SEM micrographs. The polysulfide with a 70 wt % sulfur feed ratio showed better surface area . TGA and DTG showed that better thermal properties and stable polysulfides can be obtained from higher amount of sulfur content. Other optimal conditions for inverse vulcanization were recorded as well, such as 60 min of reaction time and 195℃. The surface was modified using NaCl as porogen to increase surface area. The BET results confirmed the increase of the surface area of the porous polysulfides prepared using NaCl. Removal performance was evaluated by studying the effects of parameters including porosity, pH of the solution, initial Fe^{3+} concentration, and amount of polysulfide dosages. The highest removal was recorded for porous polysulfides. Acidic pH (pH=3) was favorable for Fe^{3+} removal. The optimum dosage was 20 mg/100 mL. The removal isotherm has been studied and fitted best for Freundlich isotherm. The kinetic study of the removal process has been fit well in linear pseudo second order kinetic model. It is concluded that inverse vulcanized polysulfides can be successfully used to reduce Fe^{3+} in wastewater and mitigate the environmental threats of excess WCO.

TABLE OF CONTENT

REFERENCES

Abas, S. N. A., Ismail, M. H. S., Kamal, M. L. & Izhar, S. (2013). Adsorption process of heavy metals by low-cost adsorbent: A review. *World Applied Sciences Journal*, *28*(11), 1518–1530. https://doi.org/10.5829/idosi.wasj.2013.28.11.1874

Abbasi, A., Nasef, M. M. & Yahya, W. Z. N. (2019). Copolymerization of vegetable oils and bio-based monomers with elemental sulfur: A new promising route for bio-based polymers. *Sustainable Chemistry and Pharmacy*, *13*(March), 100158. https://doi.org/10.1016/j.scp.2019.100158

Abbasi, A., Nasef, M. M. & Yahya, W. Z. N. (2020). Sulfur Based Polymers by Inverse Vulcanization: a Novel Path to Foster Green Chemistry. *Green Materials*, 1–8. https://doi.org/10.1680/jgrma.19.00053

Abbasi, A., Nasef, M. M., Yahya, W. Z. N., Moniruzzaman, M. & Ghumman, A. S. (2020). Preparation and characterization of green polymer by copolymerization of corn oil and sulphur at molten state. *Polymers and Polymer Composites*. https://doi.org/10.1177/0967391120959536

Abbasi, A., Yahya, W. Z. N. & Nasef, M. M. (2020). Sulfur-based polymers by inverse vulcanization: A novel path to foster green chemistry. *Green Materials*, *8*(4), 172–180. https://doi.org/10.1680/jgrma.19.00053

Abdullah, N. & Sulaiman, F. (2013). The Oil Palm Wastes in Malaysia, Biomass Now-Sustainable Growth and Use. *Biomass Now - Sustainable Growth and Use*, 75–100. https://doi.org/10.5772/55302

Abraham, A. M., Kumar, S. V. & Alhassan, S. M. (2018a). Porous sulphur copolymer for gas-phase mercury removal and thermal insulation. *Chemical Engineering Journal*, *332*(September 2017), 1–7. https://doi.org/10.1016/j.cej.2017.09.069

Abraham, A. M., Kumar, S. V. & Alhassan, S. M. (2018b). Porous sulphur copolymer for gas-phase mercury removal and thermal insulation. *Chemical Engineering Journal*, *332*, 1–7. https://doi.org/10.1016/J.CEJ.2017.09.069

Adams, P. C. (2015). Epidemiology and diagnostic testing for hemochromatosis and iron overload. *International Journal of Laboratory Hematology*, *37*(S1), 25–30. https://doi.org/10.1111/ijlh.12347

Ahmed, I. & Jhung, S. H. (2017). Applications of metal-organic frameworks in adsorption/separation processes via hydrogen bonding interactions. *Chemical Engineering Journal*, *310*, 197–215. https://doi.org/10.1016/J.CEJ.2016.10.115

Ain, N., Hassan, M. & Kushairi, A. (2018). MALAYSIA: 100 YEARS OF RESILIENT PALM

OIL ECONOMIC PERFORMANCE. *Journal of Oil Palm Research*, *30*(1), 13–25. https://doi.org/10.21894/jopr.2018.0014

Akay, S., Kayan, B., Kalderis, D., Arslan, M., Yagci, Y. & Kiskan, B. (2017). Poly(benzoxazine-co-sulfur): An efficient sorbent for mercury removal from aqueous solution. *Journal of Applied Polymer Science*, *134*(38), 1–11. https://doi.org/10.1002/app.45306

Akbari-Adergani, B., Memarzadeh, N., Ghoreyshi, A. A. & Pirzadeh, K. (2016). Highly Concentrated Ferrus Removal From Groundwater Using Powdered Activated Carbon As Adsorbent. *Journal of Chemical Health Risks (Jchr)*, *7*(4), 273–284. https://doi.org/10.22034/jchr.2018.544188

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. https://doi.org/10.1016/J.EJAR.2018.07.006

Alimohammadi, V., Sedighi, M. & Jabbari, E. (2017). Experimental study on efficient removal of total iron from wastewater using magnetic-modified multi-walled carbon nanotubes. *Ecological Engineering*, *102*, 90–97. https://doi.org/10.1016/j.ecoleng.2017.01.044

Aslam, M. M.-A., Kuo, H.-W., Den, W., Usman, M., Sultan, M. & Ashraf, H. (2021). Functionalized Carbon Nanotubes (CNTs) for Water and Wastewater Treatment: Preparation to Application. *Sustainability*, *13*(10), 5717. https://doi.org/10.3390/SU13105717

Atabani, A. E., Shobana, S., Mohammed, M. N., Uğuz, G., Kumar, G., Arvindnarayan, S., Aslam, M. & Al-Muhtaseb, A. H. (2019). Integrated valorization of waste cooking oil and spent coffee grounds for biodiesel production: Blending with higher alcohols, FT–IR, TGA, DSC and NMR characterizations. *Fuel*, *244*, 419–430. https://doi.org/10.1016/J.FUEL.2019.01.169

Awad, A. M., Shaikh, S. M. R., Jalab, R., Gulied, M. H., Nasser, M. S., Benamor, A. & Adham, S. (2019). Adsorption of organic pollutants by natural and modified clays: A comprehensive review. *Separation and Purification Technology*, *228*, 115719. https://doi.org/10.1016/J.SEPPUR.2019.115719

Ayawei, N., Ebelegi, A. N. & Wankasi, D. (2017). Modelling and Interpretation of Adsorption Isotherms. *Journal of Chemistry*, *2017*. https://doi.org/10.1155/2017/3039817

Bashi, A. M., Haddawi, S. M. & Mohammad, W. N. (2010). Kienetic study of adsorptions cations of Ni + 2 , Co + 2 and Fe + 3 on the surfaces of amorphous Titanium phosphate حطس بلع ذيذحلاو ثلبوكلاو لكينلا تانوياتك زاستملا ةيكرح ةسارد موينياتيتلا تافسوف. *Journal of Kerbala University*, *8*(2), 1–6.

Bastos-neto, M., Cristina, D. & Azevedo, S. De. (2020). *Adsorption 1*. https://doi.org/10.1002/0471238961.0104191518212008.a01.pub3

Bear, J. C., McGettrick, J. D., Parkin, I. P., Dunnill, C. W. & Hasell, T. (2016). Porous carbons from inverse vulcanised polymers. *Microporous and Mesoporous Materials*, *232*, 189–195. https://doi.org/10.1016/J.MICROMESO.2016.06.021

Belova, T. P. (2019). Adsorption of heavy metal ions (Cu2+, Ni2+, Co2+ and Fe2+) from aqueous solutions by natural zeolite. *Heliyon*, *5*(9), e02320. https://doi.org/10.1016/J.HELIYON.2019.E02320

Beni, A. A. & Esmaeili, A. (2020). Biosorption, an efficient method for removing heavy metals from industrial effluents: A Review. *Environmental Technology & Innovation*, *17*, 100503. https://doi.org/10.1016/J.ETI.2019.100503

Bhateria, R. & Singh, R. (2019). A review on nanotechnological application of magnetic iron oxides for heavy metal removal. *Journal of Water Process Engineering*, *31*, 100845. https://doi.org/10.1016/J.JWPE.2019.100845

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. https://doi.org/10.1039/C8CS00493E

Boyd, D. A. (2016). Sulfur and Its Role In Modern Materials Science. *Angewandte Chemie - International Edition*, *55*(50), 15486–15502. https://doi.org/10.1002/anie.201604615

Bu Najmah, I., Lundquist, N. A., Stanfield, M. K., Stojcevski, F., Campbell, J. A., Esdaile, L. J., Gibson, C. T., Lewis, D. A., Henderson, L. C., Hasell, T. & Chalker, J. M. (2021). Insulating Composites Made from Sulfur, Canola Oil, and Wool**. *ChemSusChem*, *14*(11), 2352–2359. https://doi.org/10.1002/cssc.202100187

Chai, W. S., Cheun, J. Y., Kumar, P. S., Mubashir, M., Majeed, Z., Banat, F., Ho, S. H. & Show, P. L. (2021). A review on conventional and novel materials towards heavy metal adsorption in wastewater treatment application. *Journal of Cleaner Production*, *296*, 126589. https://doi.org/10.1016/J.JCLEPRO.2021.126589

Chai, W. S., Tan, W. G., Halimatul Munawaroh, H. S., Gupta, V. K., Ho, S. H. & Show, P. L. (2021). Multifaceted roles of microalgae in the application of wastewater biotreatment: A review. *Environmental Pollution*, *269*, 116236. https://doi.org/10.1016/J.ENVPOL.2020.116236

Chalker, J. M., Mann, M., Worthington, M. J. H. & Esdaile, L. J. (2021). Polymers Made by Inverse Vulcanization for Use as Mercury Sorbents. *Organic Materials*, *03*(02), 362–373. https://doi.org/10.1055/a-1502-2611

Chalker, J. M., Worthington, M. J. H., Lundquist, N. A. & Esdaile, L. J. (2019). Synthesis and Applications of Polymers Made by Inverse Vulcanization. *Topics in Current Chemistry*, *377*(3), 1–27. https://doi.org/10.1007/s41061-019-0242-7

Cheang, E. K., Cheang, T. K. & Tay, Y. H. (2017). Using Convolutional Neural Networks to Count Palm Trees in Satellite Images. *Earth Syst. Sci. Data*, *12*(2), 847–867. http://arxiv.org/abs/1701.06462

Chen, C., Chitose, A., Kusadokoro, M., Nie, H., Xu, W., Yang, F. & Yang, S. (2021). Sustainability and challenges in biodiesel production from waste cooking oil: An advanced bibliometric analysis. *Energy Reports*, *7*, 4022–4034. https://doi.org/10.1016/J.EGYR.2021.06.084

Chen, L.-H., Sun, M.-H., Wang, Z., Yang, W., Xie, Z. & Su, B.-L. (2020). Hierarchically Structured Zeolites: From Design to Application. *Chemical Reviews*, *120*(20), 11194–11294. https://doi.org/10.1021/ACS.CHEMREV.0C00016

Chen, Yiqin, Wang, Y., Zheng, R., Wen, J., Li, J. Y., Wang, Q. & Yin, J. (2020). Stabilization of heavy metals in sediments: A bioavailability-based assessment of carbon adsorbent efficacy using diffusive gradients in thin films. *Aquaculture and Fisheries*. https://doi.org/10.1016/J.AAF.2020.07.007

Chen, Yurong, Yasin, A., Zhang, Y., Zan, X., Liu, Y. & Zhang, L. (2020). Preparation and modification of biomass-based functional rubbers for removing mercury(II) from aqueous solution. *Materials*, *13*(3). https://doi.org/10.3390/ma13030632

Chinglenthoiba, C., Das, A. & Vandana, S. (2020). Enhanced biodiesel production from waste cooking palm oil, with NaOH-loaded Calcined fish bones as the catalyst. *Environmental Science and Pollution Research 2020 27:13*, *27*(13), 15925–15930. https://doi.org/10.1007/S11356-020-08249-7

Choudhury, S., Srimuk, P., Raju, K., Tolosa, A., Fleischmann, S., Zeiger, M., Ozoemena, K. I., Borchardt, L. & Presser, V. (2018). Carbon onion/sulfur hybrid cathodes: Via inverse vulcanization for lithium-sulfur batteries. *Sustainable Energy and Fuels*, *2*(1), 133–146. https://doi.org/10.1039/c7se00452d

Chung, W. J., Griebel, J. J., Kim, E. T., Yoon, H., Simmonds, A. G., Ji, H. J., Dirlam, P. T., Glass, R. S., Wie, J. J., Nguyen, N. A., Guralnick, B. W., Park, J., Somogyi, Á., Theato, P., Mackay, M. E., Sung, Y. E., Char, K. & Pyun, J. (2013). The use of elemental sulfur as an alternative feedstock for polymeric materials. *Nature Chemistry*, *5*(6), 518–524. https://doi.org/10.1038/nchem.1624

Comyn, J. (2021). What are adhesives and sealants and how do they work? In R. D. Adams (Ed.), *Adhesive Bonding* (2nd ed., pp. 41–78). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-819954-1.00003-4

Crini, G., Lichtfouse, E., Wilson, L., Morin-crini, N., Crini, G., Lichtfouse, E., Wilson, L., Adsorption-oriented, N. M., Crini, G., Lichtfouse, E., Wilson, L. D. & Morin-crini, N. (2019). Adsorption-oriented processes using conventional and non-conventional adsorbents for wastewater treatment To cite this version : HAL Id : hal-02065600 Adsorption-Oriented Processes Using Conventional and Non-conventional Adsorbents for Wastewater Treatmen.

In *Environmental Chemistry for a Sustainable World.* (Vol. 18).

Crockett, M. P., Evans, A. M., Worthington, M. J. H., Albuquerque, I. S., Slattery, A. D., Gibson, C. T., Campbell, J. A., Lewis, D. A., Bernardes, G. J. L. & Chalker, J. M. (2015). Sulfur-Limonene Polysulfide: A Material Synthesized Entirely from Industrial By-Products and Its Use in Removing Toxic Metals from Water and Soil. *Angewandte Chemie - International Edition*, *55*(5), 1714–1718. https://doi.org/10.1002/anie.201508708

Daiber, A., Kuntic, M., Hahad, O., Delogu, L. G., Rohrbach, S., Di Lisa, F., Schulz, R. & Münzel, T. (2020). Effects of air pollution particles (ultrafine and fine particulate matter) on mitochondrial function and oxidative stress – Implications for cardiovascular and neurodegenerative diseases. *Archives of Biochemistry and Biophysics*, *696*, 108662. https://doi.org/10.1016/J.ABB.2020.108662

Degfie, T. A., Mamo, T. T. & Mekonnen, Y. S. (2019). Optimized Biodiesel Production from Waste Cooking Oil (WCO) using Calcium Oxide (CaO) Nano-catalyst. *Scientific Reports 2019 9:1*, *9*(1), 1–8. https://doi.org/10.1038/s41598-019-55403-4

Deng, F., Luo, X. B., Ding, L. & Luo, S. L. (2019). Application of Nanomaterials and Nanotechnology in the Reutilization of Metal Ion From Wastewater. *Nanomaterials for the Removal of Pollutants and Resource Reutilization*, 149–178. https://doi.org/10.1016/B978-0-12-814837-2.00005-6

Diez, S., Hoefling, A., Theato, P. & Pauer, W. (2017). Mechanical and electrical properties of sulfur-containing polymeric materials prepared via inverse vulcanization. *Polymers*, *9*(2), 1–16. https://doi.org/10.3390/polym9020059

Dirlam, P. T., Simmonds, A. G., Kleine, T. S., Nguyen, N. A., Anderson, L. E., Klever, A. O., Florian, A., Costanzo, P. J., Theato, P., Mackay, M. E., Glass, R. S., Char, K. & Pyun, J. (2015). Inverse vulcanization of elemental sulfur with 1,4-diphenylbutadiyne for cathode materials in Li–S batteries. *RSC Advances*, *5*(31), 24718–24722. https://doi.org/10.1039/C5RA01188D

Dodd, L. J., Omar, Ö., Wu, X. & Hasell, T. (2021). Investigating the Role and Scope of Catalysts in Inverse Vulcanization. *ACS Catalysis*, *11*(8), 4441–4455. https://doi.org/10.1021/ACSCATAL.0C05010/SUPPL_FILE/CS0C05010_SI_002.MP4

Dong, X. L., Li, W. C., Jiang, B., Zhou, Y. Q. & Lu, A. H. (2019). Using inorganic dynamic porogens for preparing high-surface-area capacitive carbons with tailored micropores. *Journal of Materials Chemistry A*, *7*(2), 687–692. https://doi.org/10.1039/C8TA10411E

Duan, C., Ma, T., Wang, J. & Zhou, Y. (2020). Removal of heavy metals from aqueous solution using carbon-based adsorbents: A review. *Journal of Water Process Engineering*, *37*, 101339. https://doi.org/10.1016/J.JWPE.2020.101339

Dvwh, R. I., Lq, R., Ri, W. K. H., Dqg, H. & Dv, D. (2018). *8Vh Ri :Dvwh &Rrnlqj 2Lo Lq Wkh*

0Dqxidfwxuh Ri 6Rdsv +. *33*(1), 2015–2016.

El-Naas, M. H., Surkatti, R. & Al-Zuhair, S. (2016). Petroleum refinery wastewater treatment: A pilot scale study. *Journal of Water Process Engineering*, *14*, 71–76. https://doi.org/10.1016/j.jwpe.2016.10.005

Elmobarak, W. F., Hameed, B. H., Almomani, F. & Abdullah, A. Z. (2021). A Review on the Treatment of Petroleum Refinery Wastewater Using Advanced Oxidation Processes. *Catalysts 2021, Vol. 11, Page 782*, *11*(7), 782. https://doi.org/10.3390/CATAL11070782

Faheem, Jianguo Bao, Han Zheng, Haseeb Tufail, Sana Irshad & Jiangkun Du. (2018). Adsorption-assisted decontamination of Hg(ii) from aqueous solution by multi-functionalized corncob-derived biochar. *RSC Advances*, *8*(67), 38425–38435. https://doi.org/10.1039/C8RA06622A

Fahimirad, B., Asghari, A. & Rajabi, M. (2017). Photo-degradation of basic green 1 and basic red 46 dyes in their binary solution by La2O3-Al2O3nanocomposite using first-order derivative spectra and experimental design methodology. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, *179*, 58–65. https://doi.org/10.1016/j.saa.2017.02.022

Fuhrmann, M., Melamed, D., Kalb, P. D., Adams, J. W. & Milian, L. W. (2002). Sulfur Polymer Solidification/Stabilization of elemental mercury waste. *Waste Management*, *22*(3), 327–333. https://doi.org/10.1016/S0956-053X(01)00057-5

Ghumman, A. S. M., Nasef, M. M., Shamsuddin, M. R. & Abbasi, A. (2020). Evaluation of properties of sulfur-based polymers obtained by inverse vulcanization: Techniques and challenges. *Polymers and Polymer Composites*. https://doi.org/10.1177/0967391120954072

Ghumman, A. S. M., Shamsuddin, R., Nasef, M. M., Nisa Yahya, W. Z. & Abbasi, A. (2021). Optimization of synthesis of inverse vulcanized copolymers from rubber seed oil using response surface methodology. *Polymer*, *219*(December 2020), 123553. https://doi.org/10.1016/j.polymer.2021.123553

Giuffrè, A. M., Capocasale, M., Macrì, R., Caracciolo, M., Zappia, C. & Poiana, M. (2020). Volatile profiles of extra virgin olive oil, olive pomace oil, soybean oil and palm oil in different heating conditions. *LWT*, *117*, 108631. https://doi.org/10.1016/J.LWT.2019.108631

Gohain, B., Saikia, P. M., Sarma, S., Bhat, S. N. & Dutta, R. K. (2002). Hydrophobicity-induced deprotonation of dye in dye–submicellar surfactant systems. *Physical Chemistry Chemical Physics*, *4*(12), 2617–2620. https://doi.org/10.1039/B201274J

Gomez, I. J., Arnaiz, B., Cacioppo, M., Arcudi, F. & Prato, M. (2018). Nitrogen-doped Carbon Nanodots for bioimaging and delivery of paclitaxel. *Journal of Materials Chemistry B*,

6(35). https://doi.org/10.1039/x0xx00000x

Gomez, I., Leonet, O., Blazquez, J. A. & Mecerreyes, D. (2016). Inverse Vulcanization of Sulfur using Natural Dienes as Sustainable Materials for Lithium–Sulfur Batteries. *ChemSusChem*, *9*(24), 3419–3425. https://doi.org/10.1002/cssc.201601474

Grazuleviciene, R., Nadisauskiene, R., Buinauskiene, J. & Grazulevicius, T. (2009). *Effects of Elevated Levels of Manganese and Iron in Drinking Water on Birth Outcomes*. *18*(5), 819–825.

Griebel, J. J., Glass, R. S., Char, K. & Pyun, J. (2016a). Polymerizations with elemental sulfur: A novel route to high sulfur content polymers for sustainability, energy and defense. *Progress in Polymer Science*, *58*, 90–125. https://doi.org/10.1016/j.progpolymsci.2016.04.003

Griebel, J. J., Glass, R. S., Char, K. & Pyun, J. (2016b). Polymerizations with elemental sulfur: A novel route to high sulfur content polymers for sustainability, energy and defense. *Progress in Polymer Science*, *58*, 90–125. https://doi.org/10.1016/j.progpolymsci.2016.04.003

Griebel, J. J., Li, G., Glass, R. S., Char, K. & Pyun, J. (2015). Kilogram scale inverse vulcanization of elemental sulfur to prepare high capacity polymer electrodes for Li-S batteries. *Journal of Polymer Science, Part A: Polymer Chemistry*, *53*(2), 173–177. https://doi.org/10.1002/pola.27314

Gupta, A. D., Rawat, K. P., Bhadauria, V. & Singh, H. (2021). Recent trends in the application of modified starch in the adsorption of heavy metals from water: A review. *Carbohydrate Polymers*, *269*, 117763. https://doi.org/10.1016/J.CARBPOL.2021.117763

Gupta, K., Joshi, P., Gusain, R. & Khatri, O. P. (2021). Recent advances in adsorptive removal of heavy metal and metalloid ions by metal oxide-based nanomaterials. *Coordination Chemistry Reviews*, *445*, 214100. https://doi.org/10.1016/J.CCR.2021.214100

Hajeb, P., Jinap, S. & Ismail, A. (2012). Preface. *Reviews of Environmental Contamination and Toxicology*, *220*, 45–66. https://doi.org/10.1007/978-1-4614-3414-6

HAMODA, M. F. & AL-HADDAD, A. A. (1987). Investigation of Petroleum Refinery Effluent Treatment in an Aerobic Fixed-film Biological System. *Water and Environment Journal*, *1*(2), 239–246. https://doi.org/10.1111/j.1747-6593.1987.tb01217.x

Han, H., Rafiq, M. K., Zhou, T., Xu, R., Mašek, O. & Li, X. (2019). A critical review of clay-based composites with enhanced adsorption performance for metal and organic pollutants. *Journal of Hazardous Materials*, *369*, 780–796. https://doi.org/10.1016/J.JHAZMAT.2019.02.003

Hasell, T., Parker, D. J., Jones, H. A., McAllister, T. & Howdle, S. M. (2016). Porous inverse vulcanised polymers for mercury capture. *Chemical Communications*, *52*(31), 5383–5386. https://doi.org/10.1039/c6cc00938g

Hasheminasab, H., Gholipour, Y., Kharrazi, M. & Streimikiene, D. (2018). A novel Metric of Sustainability for petroleum refinery projects. *Journal of Cleaner Production*, *171*, 1215–1224. https://doi.org/10.1016/J.JCLEPRO.2017.09.223

Hernández-Cocoletzi, H., Salinas, R. A., Águila-Almanza, E., Rubio-Rosas, E., Chai, W. S., Chew, K. W., Mariscal-Hernández, C. & Show, P. L. (2020). Natural hydroxyapatite from fishbone waste for the rapid adsorption of heavy metals of aqueous effluent. *Environmental Technology & Innovation*, *20*, 101109. https://doi.org/10.1016/J.ETI.2020.101109

Herrera, C., Ysinga, K. J. & Jenkins, C. L. (2019). Polysulfides Synthesized from Renewable Garlic Components and Repurposed Sulfur Form Environmentally Friendly Adhesives [Research-article]. *ACS Applied Materials and Interfaces*, *11*(38), 35312–35318. https://doi.org/10.1021/acsami.9b11204

Ho, S. H., Chen, Y. di, Yang, Z. kai, Nagarajan, D., Chang, J. S. & Ren, N. qi. (2017). High-efficiency removal of lead from wastewater by biochar derived from anaerobic digestion sludge. *Bioresource Technology*, *246*, 142–149. https://doi.org/10.1016/J.BIORTECH.2017.08.025

Hodaifa, G., Ochando-Pulido, J. M., Driss Alami, S. Ben, Rodriguez-Vives, S. & Martinez-Ferez, A. (2013). Kinetic and thermodynamic parameters of iron adsorption onto olive stones. *Industrial Crops and Products*, *49*, 526–534. https://doi.org/10.1016/j.indcrop.2013.05.039

Hoefling, A., Lee, Y. J. & Theato, P. (2017). Sulfur-Based Polymer Composites from Vegetable Oils and Elemental Sulfur: A Sustainable Active Material for Li–S Batteries. *Macromolecular Chemistry and Physics*, *218*(1), 1–9. https://doi.org/10.1002/macp.201600303

Hong, M., Yu, L., Wang, Y., Zhang, J., Chen, Z., Dong, L., Zan, Q. & Li, R. (2019). Heavy metal adsorption with zeolites: The role of hierarchical pore architecture. *Chemical Engineering Journal*, *359*, 363–372. https://doi.org/10.1016/J.CEJ.2018.11.087

Hossain, K. & Ahmed, R. Bin. (2019). *Application of Waste Cooking Oil in Construction of Asphalt Pavement*. *June*.

Ibrahim, H. M. & Zairy, E. M. R. E.-. (2015). Chitosan as a Biomaterial — Structure, Properties, and Electrospun Nanofibers. In V. Bobbarala (Ed.), *Concepts, Compounds and the Alternatives of Antibacterials* (1st ed., pp. 81–101). IntechOpen. https://doi.org/10.5772/61300

Ibrahim, M. F., Hod, R., Sahani, M., Nawi, A. M., Idris, I. B., Yusoff, H. M. & Toha, H. R. (2021). The Impacts of Illegal Toxic Waste Dumping on Children's Health: A Review and

Case Study from Pasir Gudang, Malaysia. *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 2221*, *18*(5), 2221. https://doi.org/10.3390/IJERPH18052221

Islam, M. A., Morton, D. W., Johnson, B. B., Mainali, B. & Angove, M. J. (2018). Manganese oxides and their application to metal ion and contaminant removal from wastewater. *Journal of Water Process Engineering*, *26*, 264–280. https://doi.org/10.1016/J.JWPE.2018.10.018

Ismail, M., Yahya, M. S., Idris, N. H., Mustafa, N. S. M. & Yap, M. F. A. A. H. (2020). Novel materials and technologies for hydrogen storage. *New Dimensions in Production and Utilization of Hydrogen*, 337–365. https://doi.org/10.1016/B978-0-12-819553-6.00014-3

J, G. J. & M, M. G. (2016). Equilibrium, kinetic and thermodynamic study on the removal of cadmium (ii) from aqueous solutions using sponge gourd (Luffa cylindrica) fibers. *Sky Journal of Soil Science and Environmental Management*, *5*(1), 1–011. http://www.skyjournals.org/SJSSEM

Jacobs, L. J. M., Kemmere, M. F. & Keurentjes, J. T. F. (2008). Sustainable polymer foaming using high pressure carbon dioxide: a review on fundamentals, processes and applications. *Green Chemistry*, *10*(7), 731–738. https://doi.org/10.1039/B801895B

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B. & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, *7*(2), 60–72. https://doi.org/10.2478/intox-2014-0009

Jin, Y., Luan, Y., Ning, Y. & Wang, L. (2018). Effects and Mechanisms of Microbial Remediation of Heavy Metals in Soil: A Critical Review. *Applied Sciences*, *8*(8), 1336. https://doi.org/10.3390/APP8081336

Karunarathna, M. S., Lauer, M. K., Thiounn, T., Smith, R. C. & Tennyson, A. G. (2019). Valorisation of waste to yield recyclable composites of elemental sulfur and lignin. *Journal of Materials Chemistry A*, *7*(26), 15683–15690. https://doi.org/10.1039/c9ta03222c

Kaveeshwar, A. R., Ponnusamy, S. K., Revellame, E. D., Gang, D. D., Zappi, M. E. & Subramaniam, R. (2018). Pecan shell based activated carbon for removal of iron(II) from fracking wastewater: Adsorption kinetics, isotherm and thermodynamic studies. *Process Safety and Environmental Protection*, *114*(Ii), 107–122. https://doi.org/10.1016/j.psep.2017.12.007

Khalid, Z. Bin, Nasrullah, M., Nayeem, A., Wahid, Z. A., Singh, L. & Krishnan, S. (2020). Application of 2D Graphene-Based Nanomaterials for Pollutant Removal from Advanced Water and Wastewater Treatment Processes. In L. Singh & D. M. Mahapatra (Eds.), *ACS Symposium Series* (1st ed., Vol. 1353, pp. 191–217). American Chemical Society. https://doi.org/10.1021/BK-2020-1353.CH009

Khayyun, T. S. & Mseer, A. H. (2019). Comparison of the experimental results with the Langmuir

and Freundlich models for copper removal on limestone adsorbent. *Applied Water Science 2019 9:8*, *9*(8), 1–8. https://doi.org/10.1007/S13201-019-1061-2

Ko, L. A., Huang, Y. S. & Lin, Y. A. (2021). Bipyridine-Containing Polysulfide Materials for Broad-Spectrum Removal of Heavy Metals from Water. *ACS Applied Polymer Materials*, *3*(7), 3363–3372. https://doi.org/10.1021/acsapm.1c00259

Lee, J.-S. M., Parker, D. J., Cooper, A. I. & Hasell, T. (2017). High surface area sulfur-doped microporous carbons from inverse vulcanised polymers. *Journal of Materials Chemistry A*, *5*(35), 18603–18609. https://doi.org/10.1039/C7TA07130B

Lee, J., Lee, S., Kim, J., Hanif, Z., Han, S., Hong, S. & Yoon, M. H. (2018). Solution-based sulfur-polymer coating on nanofibrillar films for immobilization of aqueous mercury ions. *Bulletin of the Korean Chemical Society*, *39*(1), 84–89. https://doi.org/10.1002/bkcs.11350

Li, J., Wang, X., Zhao, G., Chen, C., Chai, Z., Alsaedi, A., Hayat, T. & Wang, X. (2018). Metal–organic framework-based materials: superior adsorbents for the capture of toxic and radioactive metal ions. *Chemical Society Reviews*, *47*(7), 2322–2356. https://doi.org/10.1039/C7CS00543A

Li, Y., Yu, H., Liu, L. & Yu, H. (2021). Application of co-pyrolysis biochar for the adsorption and immobilization of heavy metals in contaminated environmental substrates. *Journal of Hazardous Materials*, *420*, 126655. https://doi.org/10.1016/J.JHAZMAT.2021.126655

Lim, S. Y., Mutalib, M. S. A., Khaza'ai, H. & Chang, S. K. (2018). Detection of fresh palm oil adulteration with recycled cooking oil using fatty acid composition and FTIR spectral analysis. *Https://Doi.Org/10.1080/10942912.2018.1522332*, *21*(1), 2428–2451. https://doi.org/10.1080/10942912.2018.1522332

Lima, E. C., Sher, F., Guleria, A., Saeb, M. R., Anastopoulos, I., Tran, H. N. & Hosseini-Bandegharaei, A. (2021). Is one performing the treatment data of adsorption kinetics correctly? *Journal of Environmental Chemical Engineering*, *9*(2), 104813. https://doi.org/10.1016/j.jece.2020.104813

Limjuco, L. A., Fissaha, H. T., Kim, H., Nisola, G. M. & Chung, W. J. (2020). Sulfur Copolymerization with Hydrophilic Comonomers as Polysulfides in Microbeads for Highly Efficient Hg2+Removal from Wastewater. *ACS Applied Polymer Materials*, *2*(11), 4677–4689. https://doi.org/10.1021/acsapm.0c00725

Limjuco, L. A., Nisola, G. M., Parohinog, K. J., Valdehuesa, K. N. G., Lee, S. P., Kim, H. & Chung, W. J. (2019). Water-insoluble hydrophilic polysulfides as microfibrous composites towards highly effective and practical Hg2+ capture. *Chemical Engineering Journal*, *378*, 122216. https://doi.org/10.1016/J.CEJ.2019.122216

Lin, H. K., Lai, Y. S. & Liu, Y. L. (2019). Cross-Linkable and Self-Foaming Polysulfide Materials for Repairable and Mercury Capture Applications. *ACS Sustainable Chemistry*

and Engineering, *7*(4), 4515–4522. https://doi.org/10.1021/acssuschemeng.8b06815

Liu, J. G. & Ueda, M. (2009). High refractive index polymers: Fundamental research and practical applications. *Journal of Materials Chemistry*, *19*(47), 8907–8919. https://doi.org/10.1039/b909690f

Lopes, M., Miranda, S. M., Alves, J. M., Pereira, A. S. & Belo, I. (2019). Waste Cooking Oils as Feedstock for Lipase and Lipid-Rich Biomass Production. *European Journal of Lipid Science and Technology*, *121*(1), 1–33. https://doi.org/10.1002/ejlt.201800188

Lopez, C. V., Karunarathna, M. S., Lauer, M. K., Maladeniya, C. P., Thiounn, T., Ackley, E. D. & Smith, R. C. (2020). High strength, acid-resistant composites from canola, sunflower, or linseed oils: Influence of triglyceride unsaturation on material properties. *Journal of Polymer Science*, *58*(16), 2259–2266. https://doi.org/10.1002/pol.20200292

Luchese, C. L., Benelli, P., Spada, J. C. & Tessaro, I. C. (2018). Impact of the starch source on the physicochemical properties and biodegradability of different starch-based films. *Journal of Applied Polymer Science*, *135*(33), 46564. https://doi.org/10.1002/APP.46564

Lundquist, N. A. & Chalker, J. M. (2020a). Confining a spent lead sorbent in a polymer made by inverse vulcanization prevents leaching. *Sustainable Materials and Technologies*, *26*, e00222. https://doi.org/10.1016/j.susmat.2020.e00222

Lundquist, N. A. & Chalker, J. M. (2020b). Confining a spent lead sorbent in a polymer made by inverse vulcanization prevents leaching. *Sustainable Materials and Technologies*, *26*, e00222. https://doi.org/10.1016/j.susmat.2020.e00222

Lundquist, N. A., Tikoalu, A. D., Worthington, M. J. H., Shapter, R., Tonkin, S. J., Stojcevski, F., Mann, M., Gibson, C. T., Gascooke, J. R., Karton, A., Henderson, L. C., Esdaile, L. J. & Chalker, J. M. (2020). Reactive Compression Molding Post-Inverse Vulcanization: A Method to Assemble, Recycle, and Repurpose Sulfur Polymers and Composites. *Chemistry - A European Journal*, *26*(44), 10035–10044. https://doi.org/10.1002/chem.202001841

Lundquist, N. A., Worthington, M. J. H., Adamson, N., Gibson, C. T., Johnston, M. R., Ellis, A. V. & Chalker, J. M. (2018a). Polysulfides made from re-purposed waste are sustainable materials for removing iron from water. *RSC Advances*, *8*(3), 1232–1236. https://doi.org/10.1039/c7ra11999b

Lundquist, N. A., Worthington, M. J. H., Adamson, N., Gibson, C. T., Johnston, M. R., Ellis, A. V. & Chalker, J. M. (2018b). Polysulfides made from re-purposed waste are sustainable materials for removing iron from water. *RSC Advances*, *8*(3), 1232–1236. https://doi.org/10.1039/c7ra11999b

Luyk, E. (2019). *Sputter Coating - SEM - Sample Preparation - Accelerating Microscopy*. https://www.thermofisher.com/blog/microscopy/sputter-coating-for-sem-how-this-sample-preparation-technique-assists-your-imaging/

M. Valko, H. M. & Cronin, and M. T. D. (2005). Metals, Toxicity and Oxidative Stress. *Current Medicinal Chemistry*, *12*(10), 1161–1208. https://doi.org/10.1289/ehp.1307996

Ma, H., Yang, J., Gao, X., Liu, Z., Liu, X. & Xu, Z. (2019). Removal of chromium (VI) from water by porous carbon derived from corn straw: Influencing factors, regeneration and mechanism. *Journal of Hazardous Materials*, *369*, 550–560. https://doi.org/10.1016/J.JHAZMAT.2019.02.063

Maarof, S., Ali, A. A. & Hashim, A. M. (2019). Molecular structures of cooking palm oil in gas phase modelled by density functional theory. *Materials Today: Proceedings*, *7*, 770–775. https://doi.org/10.1016/J.MATPR.2018.12.073

Maher, B. A. (2019). Airborne Magnetite- and Iron-Rich Pollution Nanoparticles: Potential Neurotoxicants and Environmental Risk Factors for Neurodegenerative Disease, Including Alzheimer's Disease. *Journal of Alzheimer's Disease*, *71*(2), 361–375. https://doi.org/10.3233/JAD-190204

Mahmoud, M. E., Abdou, A. E. H., Sobhy, M. E. & Fekry, N. A. (2017). Solid–solid crosslinking of carboxymethyl cellulose nanolayer on titanium oxide nanoparticles as a novel biocomposite for efficient removal of toxic heavy metals from water. *International Journal of Biological Macromolecules*, *105*, 1269–1278. https://doi.org/10.1016/J.IJBIOMAC.2017.07.156

Manaf, L. A., Samah, M. A. A. & Zukki, N. I. M. (2009). Municipal solid waste management in Malaysia: Practices and challenges. *Waste Management*, *29*(11), 2902–2906. https://doi.org/10.1016/j.wasman.2008.07.015

Mann, M., Kruger, J. E., Andari, F., McErlean, J., Gascooke, J. R., Smith, J. A., Worthington, M. J. H., McKinley, C. C. C., Campbell, J. A., Lewis, D. A., Hasell, T., Perkins, M. V. & Chalker, J. M. (2019). Sulfur polymer composites as controlled-release fertilisers. *Organic and Biomolecular Chemistry*, *17*(7), 1929–1936. https://doi.org/10.1039/c8ob02130a

Mann, M., Luo, X., Tikoalu, A. D., Gibson, C. T., Yin, Y., Al-Attabi, R., Andersson, G. G., Raston, C. L., Henderson, L. C., Pring, A., Hasell, T. & Chalker, J. M. (2021). Carbonisation of a polymer made from sulfur and canola oil. *Chemical Communications*, *57*(51), 6296–6299. https://doi.org/10.1039/d1cc01555a

Manthiram, A., Fu, Y., Chung, S. H., Zu, C. & Su, Y. S. (2014). Rechargeable lithium-sulfur batteries. *Chemical Reviews*, *114*(23), 11751–11787. https://doi.org/10.1021/cr500062v

Marchetti, R., Vasmara, C., Bertin, L. & Fiume, F. (2020). Conversion of waste cooking oil into biogas: perspectives and limits. *Applied Microbiology and Biotechnology*, 2833–2856. https://doi.org/10.1007/s00253-020-10431-3

Marcolongo, J. P., Zeida, A., Slep, L. D. & Olabe, J. A. (2017). Thionitrous Acid/Thionitrite and Perthionitrite Intermediates in the "Crosstalk" of NO and H2S. *Advances in Inorganic*

Chemistry, *70*, 277–309. https://doi.org/10.1016/BS.ADIOCH.2017.02.002

Mariana, M., Abdul, A. K., Mistar, E. M., Yahya, E. B., Alfatah, T., Danish, M. & Amayreh, M. (2021). Recent advances in activated carbon modification techniques for enhanced heavy metal adsorption. *Journal of Water Process Engineering*, *43*, 102221. https://doi.org/10.1016/J.JWPE.2021.102221

Md Badrul Hisham, N. H., Ibrahim, M. F., Ramli, N. & Abd-Aziz, S. (2019). Production of biosurfactant produced from used cooking oil by Bacillus sp. HIP3 for heavy metals removal. *Molecules*, *24*(14). https://doi.org/10.3390/molecules24142617

Mikhak, Y., Torabi, M. M. A. & Fouladitajar, A. (2019). Refinery and petrochemical wastewater treatment. *Sustainable Water and Wastewater Processing*, 55–91. https://doi.org/10.1016/B978-0-12-816170-8.00003-X

Mohamed, M. H. & Wilson, L. D. (2012). Porous Copolymer Resins: Tuning Pore Structure and Surface Area with Non Reactive Porogens. *Nanomaterials*, *2*(2), 163. https://doi.org/10.3390/NANO2020163

Monie, F., Vidil, T., Grignard, B., Cramail, H. & Detrembleur, C. (2021). Self-foaming polymers: Opportunities for the next generation of personal protective equipment. *Materials Science and Engineering: R: Reports*, *145*, 100628. https://doi.org/10.1016/J.MSER.2021.100628

Mostafa, K. M. & EL-Sanabary, A. A. (2020). Green and efficient tool for grafting acrylonitrile onto starch nanoparticles using microwave irradiation. *Journal of Polymer Research 2020 27:4*, *27*(4), 1–10. https://doi.org/10.1007/S10965-020-02069-6

Naderi, M. (2015). Surface Area: Brunauer-Emmett-Teller (BET). *Progress in Filtration and Separation*, 585–608. https://doi.org/10.1016/B978-0-12-384746-1.00014-8

Nakano, K., Tatsumi, G. & Nozaki, K. (2007). Synthesis of sulfur-rich polymers: Copolymerization of episulfide with carbon disulfide by using [PPN]Cl/(salph)Cr(III)Cl system. *Journal of the American Chemical Society*, *129*(49), 15116–15117. https://doi.org/10.1021/ja076056b

Nayak, P. K., Dash, U., Rayaguru, K. & Krishnan, K. R. (2016). Physio-Chemical Changes During Repeated Frying of Cooked Oil: A Review. *Journal of Food Biochemistry*, *40*(3), 371–390. https://doi.org/10.1111/JFBC.12215

Nayeem, A., Ali, M. F. & Shariffuddin, J. H. (2022a). The recent development of inverse vulcanized polysulfide as an alternative adsorbent for heavy metal removal in wastewater. *Environmental Research*, *216*(P1), 114306. https://doi.org/10.1016/j.envres.2022.114306

Nayeem, A., Ali, M. F. & Shariffuddin, J. H. (2022b). Synthesis and applications of inverse vulcanized polysulfides from bio-crosslinkers. *Materials Today: Proceedings*, *57*, 1095–

1100. https://doi.org/10.1016/J.MATPR.2021.09.397

Nguyen, T. B. (2017). Recent Advances in Organic Reactions Involving Elemental Sulfur. *Advanced Synthesis and Catalysis*, *359*(7), 1066–1130. https://doi.org/10.1002/adsc.201601329

Niño, E., Tseng, Y.-H., Ding, R., Huang, X.-M., Awogbemi, O., Onuh, E. I. & Komolafe, C. A. (2019). Thermal Degradation and Spectroscopic study of Neat Palm Oil, Waste Palm Oil, and Waste Palm Oil Methyl Ester. *IOP Conference Series: Earth and Environmental Science*, *331*(1), 012032. https://doi.org/10.1088/1755-1315/331/1/012032

Okutsu, R., Suzuki, Y., Ando, S. & Ueda, M. (2008). Poly(thioether sulfone) with high refractive index and high Abbe's number. *Macromolecules*, *41*(16), 6165–6168. https://doi.org/10.1021/ma800797p

Omeir, M. Y., Wadi, V. S. & Alhassan, S. M. (2020). Inverse vulcanized sulfur–cycloalkene copolymers: Effect of ring size and unsaturation on thermal properties. *Materials Letters*, *259*, 126887. https://doi.org/10.1016/j.matlet.2019.126887

Panadare, D. C. & Rathod, V. K. (2015). *Applications of Waste Cooking Oil Other Than Biodiesel : A Review*. *12*(3), 55–76.

Parker, D. J., Jones, H. A., Petcher, S., Cervini, L., Griffin, J. M., Akhtar, R. & Hasell, T. (2017). Low cost and renewable sulfur-polymers by inverse vulcanisation, and their potential for mercury capture. *Journal of Materials Chemistry A*, *5*(23), 11682–11692. https://doi.org/10.1039/c6ta09862b

Parker, Douglas J., Chong, S. T. & Hasell, T. (2018). Sustainable inverse-vulcanised sulfur polymers. *RSC Advances*, *8*(49), 27892–27899. https://doi.org/10.1039/c8ra04446e

Petcher, S., Parker, D. J. & Hasell, T. (2019). Macroporous sulfur polymers from a sodium chloride porogen - A low cost, versatile remediation material. *Environmental Science: Water Research and Technology*, *5*(12), 2142–2149. https://doi.org/10.1039/c9ew00477g

Petcher, S., Zhang, B. & Hasell, T. (2021). Mesoporous knitted inverse vulcanised polymers. *Chemical Communications*, *57*(41), 5059–5062. https://doi.org/10.1039/D1CC01152A

Poissier, A., Ganeshan, S. & Fernández-Serra, M. V. (2011). The role of hydrogen bonding in water–metal interactions. *Physical Chemistry Chemical Physics*, *13*(8), 3375–3384. https://doi.org/10.1039/C0CP00994F

Prabhakar, R. & Samadder, S. R. (2018). Low cost and easy synthesis of aluminium oxide nanoparticles for arsenite removal from groundwater: A complete batch study. *Journal of Molecular Liquids*, *250*, 192–201. https://doi.org/10.1016/J.MOLLIQ.2017.11.173

Putra Jaya, R., Lopa, R. S., Abdul Hassan, N., Yaacob, H., Idris Ali, M., Abdul Hamid, N. H. & Abdullah, M. E. (2018). Performance of Waste Cooking Oil on Aged Asphalt Mixture. *E3S Web of Conferences*, *65*, 1–8. https://doi.org/10.1051/e3sconf/20186502002

Qin, H., Hu, T., Zhai, Y., Lu, N. & Aliyeva, J. (2020). The improved methods of heavy metals removal by biosorbents: A review. *Environmental Pollution*, *258*, 113777. https://doi.org/10.1016/J.ENVPOL.2019.113777

Ren, Z., Jiang, X., Liu, L., Yin, C., Wang, S. & Yang, X. (2021). Modification of high-sulfur polymer using a mixture porogen and its application as advanced adsorbents for Au(III) from wastewater. *Journal of Molecular Liquids*, *328*, 115437. https://doi.org/10.1016/j.molliq.2021.115437

Renu, Agarwal, M. & Singh, K. (2017). Heavy metal removal from wastewater using various adsorbents: A review. *Journal of Water Reuse and Desalination*, *7*(4), 387–419. https://doi.org/10.2166/wrd.2016.104

Revellame, E. D., Fortela, D. L., Sharp, W., Hernandez, R. & Zappi, M. E. (2020). Adsorption kinetic modeling using pseudo-first order and pseudo-second order rate laws: A review. *Cleaner Engineering and Technology*, *1*(December), 100032. https://doi.org/10.1016/j.clet.2020.100032

Rezaei, F. & Vione, D. (2018). Effect of pH on Zero Valent Iron Performance in Heterogeneous Fenton and Fenton-Like Processes: A Review. *Molecules 2018, Vol. 23, Page 3127*, *23*(12), 3127. https://doi.org/10.3390/MOLECULES23123127

Rios, P. F., Dodiuk, H., Kenig, S., McCarthy, S. & Dotan, A. (2007). The effect of polymer surface on the wetting and adhesion of liquid systems. *Journal of Adhesion Science and Technology*, *21*(3–4), 227–241. https://doi.org/10.1163/156856107780684567

Rose, E. P., Rajam, S. & Rose, E. P. (2012). Equilibrium study of the adsorption of iron (II) ions from aqueous solution on carbons from wild jack and jambul. *Advances in Applied Science Research*, *3*(2), 1889–1894.

Ruíz, A. A. B. (2015). *Principles of Water Treatment* (Vol. 3, Issue 2).

Sahar, Sadaf, S., Iqbal, J., Ullah, I., Bhatti, H. N., Nouren, S., Habib-ur-Rehman, Nisar, J. & Iqbal, M. (2018). Biodiesel production from waste cooking oil: An efficient technique to convert waste into biodiesel. *Sustainable Cities and Society*, *41*, 220–226. https://doi.org/10.1016/J.SCS.2018.05.037

Saleh, T. A., Sari, A. & Tuzen, M. (2017). Optimization of parameters with experimental design for the adsorption of mercury using polyethylenimine modified-activated carbon. *Journal of Environmental Chemical Engineering*, *5*(1), 1079–1088. https://doi.org/10.1016/J.JECE.2017.01.032

Sankaran, R., Show, P. L., Ooi, C.-W., Ling, T. C., Shu-Jen, C., Chen, S.-Y. & Chang, Y.-K. (2020). Feasibility assessment of removal of heavy metals and soluble microbial products from aqueous solutions using eggshell wastes. *Clean Technologies and Environmental Policy 2020 22:4*, *22*(4), 773–786. https://doi.org/10.1007/S10098-019-01792-Z

Seib, M. D., Berg, K. J. & Zitomer, D. H. (2016). Low energy anaerobic membrane bioreactor for municipal wastewater treatment. *Journal of Membrane Science*, *514*, 450–457. https://doi.org/10.1016/J.MEMSCI.2016.05.007

Shaban, S. A. (2012). Biodiesel production from waste cooking oil. *Egyptian Journal of Chemistry*, *55*(5), 437–452. https://doi.org/10.18510/ijsrtm.2015.383

Shahbandeh, M. (2021). *Vegetable oils: global consumption by oil type 2013/14 to 2020/2021*. Statista. https://www.statista.com/statistics/263937/vegetable-oils-global-consumption/

Shayegan, H., Ali, G. A. M. & Safarifard, V. (2020). Recent Progress in the Removal of Heavy Metal Ions from Water Using Metal-Organic Frameworks. *ChemistrySelect*, *5*(1), 124–146. https://doi.org/10.1002/SLCT.201904107

Sheeka, Subramani, B., Shrihari, S., Manu, B. & Babunarayan, K. S. (2019). Evaluation of pyrolyzed areca husk as a potential adsorbent for the removal of Fe2+ ions from aqueous solutions. *Journal of Environmental Management*, *246*, 345–354. https://idr.nitk.ac.in/jspui/handle/123456789/11078

Shin, H., Kim, J., Kim, D., Nguyen, V. H., Lee, S., Han, S., Lim, J. & Char, K. (2018). Aqueous "polysulfide-ene" polymerization for sulfur-rich nanoparticles and their use in heavy metal ion remediation. *Journal of Materials Chemistry A*, *6*(46), 23542–23549. https://doi.org/10.1039/c8ta05457f

Shin, J., Lee, Y. G., Lee, S. H., Kim, S., Ochir, D., Park, Y., Kim, J. & Chon, K. (2020). Single and competitive adsorptions of micropollutants using pristine and alkali-modified biochars from spent coffee grounds. *Journal of Hazardous Materials*, *400*, 123102. https://doi.org/10.1016/J.JHAZMAT.2020.123102

Shokoohi, R., Asgari, G., Leili, M., Khiadani, M., Foroughi, M. & Sedighi Hemmat, M. (2017). Modelling of moving bed biofilm reactor (MBBR) efficiency on hospital wastewater (HW) treatment: a comprehensive analysis on BOD and COD removal. *International Journal of Environmental Science and Technology 2017 14:4*, *14*(4), 841–852. https://doi.org/10.1007/S13762-017-1255-9

Shukla, S., Ghosh, A., Sen, U. K., Roy, P. K., Mitra, S. & Lochab, B. (2016). Cardanol benzoxazine-Sulfur Copolymers for Li-S batteries: Symbiosis of Sustainability and Performance. *ChemistrySelect*, *1*(3), 594–600. https://doi.org/10.1002/slct.201600050

Sing, K. S. W. (2014). Assessment of Surface Area by Gas Adsorption. In J. Rouquerol, F. Rouquerol, P. Llewellyn, G. Maurin & K. Sing (Eds.), *Adsorption by Powders and Porous*

Solids: Principles, Methodology and Applications: Second Edition (2nd ed., pp. 237–268). Academic Press. https://doi.org/10.1016/B978-0-08-097035-6.00007-3

Singh, A. K. (2016). Nanoparticle Ecotoxicology. In *Engineered Nanoparticles* (pp. 343–450). Academic Press. https://doi.org/10.1016/B978-0-12-801406-6.00008-X

Smith, J. A., Wu, X., Berry, N. G. & Hasell, T. (2018). High sulfur content polymers: The effect of crosslinker structure on inverse vulcanization. *Journal of Polymer Science, Part A: Polymer Chemistry*, *56*(16), 1777–1781. https://doi.org/10.1002/pola.29067

Steudel, R. (2006). Sulfur : Organic Polysulfanes. In *Encyclopedia of Inorganic Chemistry*. John Wiley & Sons, Ltd. https://doi.org/10.1002/0470862106.ia233.pub2

Steudel, R. & Steudel, Y. (2013). Polysulfide chemistry in sodium-sulfur batteries and related systems - A computational study by G3X(MP2) and PCM calculations. *Chemistry - A European Journal*, *19*(9), 3162–3176. https://doi.org/10.1002/chem.201203397

Sultana, M., Rownok, M. H., Sabrin, M., Rahaman, M. H. & Alam, S. M. N. (2022). A review on experimental chemically modified activated carbon to enhance dye and heavy metals adsorption. *Cleaner Engineering and Technology*, *6*, 100382. https://doi.org/10.1016/J.CLET.2021.100382

Sun, Y., Liu, Y., Chen, J., Huang, Y., Lu, H., Yuan, W., Yang, Q., Hu, J., Yu, B., Wang, D., Xu, W. & Wang, H. (2021). Physical pretreatment of petroleum refinery wastewater instead of chemicals addition for collaborative removal of oil and suspended solids. *Journal of Cleaner Production*, *278*, 123821. https://doi.org/10.1016/J.JCLEPRO.2020.123821

Suzuki, Y., Murakami, K., Ando, S., Higashihara, T. & Ueda, M. (2011). Synthesis and characterization of thianthrene-based poly(phenylene sulfide)s with high refractive index over 1.8. *Journal of Materials Chemistry*, *21*(39), 15727–15731. https://doi.org/10.1039/c1jm12402a

Takahashi, T., Yamagata, M. & Ishikawa, M. (2015). A sulfur–microporous carbon composite positive electrode for lithium/sulfur and silicon/sulfur rechargeble batteries. *Progress in Natural Science: Materials International*, *25*(6), 612–621. https://doi.org/10.1016/J.PNSC.2015.11.011

Tan, K. L. & Hameed, B. H. (2017). Insight into the adsorption kinetics models for the removal of contaminants from aqueous solutions. *Journal of the Taiwan Institute of Chemical Engineers*, *74*, 25–48. https://doi.org/10.1016/j.jtice.2017.01.024

Tang, Y. Z., Gin, K. Y. H. & Aziz, M. A. (2003). The relationship between pH and heavy metal ion sorption by algal biomass. *Adsorption Science and Technology*, *21*(6), 525–538. https://doi.org/10.1260/026361703771953587

Thielke, M. W., Bultema, L. A., Brauer, D. D., Richter, B., Fischer, M. & Theato, P. (2016). Rapid Mercury(II) removal by electrospun sulfur copolymers. *Polymers*, *8*(7), 1–9. https://doi.org/10.3390/polym8070266

Tien, C. (2019a). Adsorption Equilibrium Relationships, Isotherm Expressions, Their Determinations, and Predictions. In *Introduction to Adsorption*. https://doi.org/10.1016/b978-0-12-816446-4.00003-8

Tien, C. (2019b). Adsorption Equilibrium Relationships, Isotherm Expressions, Their Determinations, and Predictions. In C. Tien (Ed.), *Introduction to Adsorption* (1st ed., pp. 23–85). Elsevier. https://doi.org/10.1016/B978-0-12-816446-4.00003-8

Tikoalu, A. D., Lundquist, N. A. & Chalker, J. M. (2020). Mercury Sorbents Made By Inverse Vulcanization of Sustainable Triglycerides: The Plant Oil Structure Influences the Rate of Mercury Removal from Water. *Advanced Sustainable Systems*, *4*(3), 1–9. https://doi.org/10.1002/adsu.201900111

Tonkin, S. J., Gibson, C. T., Campbell, J. A., Lewis, D. A., Karton, A., Hasell, T. & Chalker, J. M. (2020). Chemically induced repair, adhesion, and recycling of polymers made by inverse vulcanization. *Chemical Science*, *11*(21), 5537–5546. https://doi.org/10.1039/d0sc00855a

Torres, E. (2020). Biosorption: A Review of the Latest Advances. *Processes 2020, Vol. 8, Page 1584*, *8*(12), 1584. https://doi.org/10.3390/PR8121584

Uddin, M. K. (2017). A review on the adsorption of heavy metals by clay minerals, with special focus on the past decade. *Chemical Engineering Journal*, *308*, 438–462. https://doi.org/10.1016/J.CEJ.2016.09.029

Ujile, A. A. (2015). *Chapter · June 2014*. *June 2014*.

Vakili, M., Deng, S., Cagnetta, G., Wang, W., Meng, P., Liu, D. & Yu, G. (2019). Regeneration of chitosan-based adsorbents used in heavy metal adsorption: A review. *Separation and Purification Technology*, *224*, 373–387. https://doi.org/10.1016/J.SEPPUR.2019.05.040

Valle, S. F., Giroto, A. S., Klaic, R., Guimarães, G. G. F. & Ribeiro, C. (2019). Sulfur fertilizer based on inverse vulcanization process with soybean oil. *Polymer Degradation and Stability*, *162*, 102–105. https://doi.org/10.1016/j.polymdegradstab.2019.02.011

Wadi, V. S., Mittal, H., Fosso-Kankeu, E., Jena, K. K. & Alhassan, S. M. (2020). Mercury removal by porous sulfur copolymers: Adsorption isotherm and kinetics studies. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *606*(July), 125333. https://doi.org/10.1016/j.colsurfa.2020.125333

Wahab, A. A. A., Chang, S. H. & Som, A. M. (2015). Characterization of Waste Cooking Oil As a Potential Green Solvent for Liquid-Liquid Extraction. *International Conference on*

Advances in Civil and Environmental Engineering 2015, *Ii*, 20–28.

Wang, L., Shi, C., Wang, L., 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. https://doi.org/10.1039/C9NR09274A

Worthington, M. J. H., Kucera, R. L., Albuquerque, I. S., Gibson, C. T., Sibley, A., Slattery, A. D., Campbell, J. A., Alboaiji, S. F. K., Muller, K. A., Young, J., Adamson, N., Gascooke, J. R., Jampaiah, D., Sabri, Y. M., Bhargava, S. K., Ippolito, S. J., Lewis, D. A., Quinton, J. S., Ellis, A. V., … Chalker, J. M. (2017). Laying Waste to Mercury: Inexpensive Sorbents Made from Sulfur and Recycled Cooking Oils. *Chemistry - A European Journal*, *23*(64), 16219–16230. https://doi.org/10.1002/chem.201702871

Worthington, M. J. H., Shearer, C. J., Esdaile, L. J., Campbell, J. A., Gibson, C. T., Legg, S. K., Yin, Y., Lundquist, N. A., Gascooke, J. R., Albuquerque, I. S., Shapter, J. G., Andersson, G. G., Lewis, D. A., Bernardes, G. J. L. & Chalker, J. M. (2018). Sustainable Polysulfides for Oil Spill Remediation: Repurposing Industrial Waste for Environmental Benefit. *Advanced Sustainable Systems*, *2*(6), 1–7. https://doi.org/10.1002/adsu.201800024

Worthington, M., Kucera, R. & Slattery, A. D. (2017). *Laying Waste to Mercury : Inexpensive Sorbents Made from Sulfur and*. *July 2018*. https://doi.org/10.1002/chem.201702871

Wu, A., Jia, J. & Luan, S. (2011). Amphiphilic PMMA/PEI core–shell nanoparticles as polymeric adsorbents to remove heavy metal pollutants. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *384*(1–3), 180–185. https://doi.org/10.1016/J.COLSURFA.2011.03.060

Wu, X., Smith, J. A., Petcher, S., Zhang, B., Parker, D. J., Griffin, J. M. & Hasell, T. (2019a). Catalytic inverse vulcanization. *Nature Communications*, *10*(1), 1–9. https://doi.org/10.1038/s41467-019-08430-8

Wu, X., Smith, J. A., Petcher, S., Zhang, B., Parker, D. J., Griffin, J. M. & Hasell, T. (2019b). Catalytic inverse vulcanization. *Nature Communications*, *10*(1), 1–9. https://doi.org/10.1038/s41467-019-08430-8

Xie, R., Jin, Y., Chen, Y. & Jiang, W. (2017). The importance of surface functional groups in the adsorption of copper onto walnut shell derived activated carbon. *Water Science and Technology*, *76*(11), 3022–3034. https://doi.org/10.2166/WST.2017.471

Yaakob, Z., Mohammad, M., Alherbawi, M., Alam, Z. & Sopian, K. (2013). Overview of the production of biodiesel from Waste cooking oil. *Renewable and Sustainable Energy Reviews*, *18*(C), 184–193. https://doi.org/10.1016/J.RSER.2012.10.016

Yu, F., Li, Y., Huang, G., Yang, C., Chen, C., Zhou, T., Zhao, Y. & Ma, J. (2020). Adsorption behavior of the antibiotic levofloxacin on microplastics in the presence of different heavy metals in an aqueous solution. *Chemosphere*, *260*, 127650.

https://doi.org/10.1016/J.CHEMOSPHERE.2020.127650

Yu, L., Ruiqi, F., Zimo, L., Wenzhe, F., Zhuoxing, W. & Xinhua, X. (2015). Preparation of Functional Carbon-Based Materials for Removal of Heavy Metals from Aqueous Solution. *Progress in Chemistry*, *27*(11), 1665. https://doi.org/10.7536/PC150401

Zaharudin, N. A., Rashid, R., Mohamed Esivan, S. M., Othman, N. & Idris, A. (2016). Review on the potential use of waste cooking palm oil in the production of high oleic palm oil via enzymatic acidolysis. *Jurnal Teknologi*, *78*(6–12), 85–99. https://doi.org/10.11113/jt.v78.9237

Zhang, B., Dodd, L. J., Yan, P. & Hasell, T. (2021). Mercury capture with an inverse vulcanized polymer formed from garlic oil , a bioderived comonomer. *Reactive and Functional Polymers*, *161*(February), 104865. https://doi.org/10.1016/j.reactfunctpolym.2021.104865

Zhang, B., Gao, H., Yan, P., Petcher, S. & Hasell, T. (2020a). Inverse vulcanization below the melting point of sulfur. *Materials Chemistry Frontiers*, *4*(2), 669–675. https://doi.org/10.1039/c9qm00606k

Zhang, B., Gao, H., Yan, P., Petcher, S. & Hasell, T. (2020b). Inverse vulcanization below the melting point of sulfur. *Materials Chemistry Frontiers*, *4*(2), 669–675. https://doi.org/10.1039/C9QM00606K

Zhang, Yueyan, Glass, R. S., Char, K. & Pyun, J. (2019). Recent advances in the polymerization of elemental sulphur, inverse vulcanization and methods to obtain functional Chalcogenide Hybrid Inorganic/Organic Polymers (CHIPs). *Polymer Chemistry*, *10*(30), 4078–4105. https://doi.org/10.1039/c9py00636b

Zhang, Yueyan, Konopka, K. M., Glass, R. S., Char, K. & Pyun, J. (2017). Chalcogenide hybrid inorganic/organic polymers (CHIPs): Via inverse vulcanization and dynamic covalent polymerizations. *Polymer Chemistry*, *8*(34), 5167–5173. https://doi.org/10.1039/c7py00587c

Zhang, Yujuan, Wang, L., Zhang, N. & Zhou, Z. (2018). Adsorptive environmental applications of MXene nanomaterials: a review. *RSC Advances*, *8*(36), 19895–19905. https://doi.org/10.1039/C8RA03077D

Zhou, Q., Liao, B., Lin, L., Qiu, W. & Song, Z. (2018). Adsorption of Cu(II) and Cd(II) from aqueous solutions by ferromanganese binary oxide–biochar composites. *Science of The Total Environment*, *615*, 115–122. https://doi.org/10.1016/J.SCITOTENV.2017.09.220

Zhou, Y., He, J., Lu, J., Liu, Y. & Zhou, Y. (2020). Enhanced removal of bisphenol A by cyclodextrin in photocatalytic systems: Degradation intermediates and toxicity evaluation. *Chinese Chemical Letters*, *31*(10), 2623–2626. https://doi.org/10.1016/J.CCLET.2020.02.008

Zhu, S. & Hamielec, A. (2012). Polymerization Kinetic Modeling and Macromolecular Reaction Engineering. *Polymer Science: A Comprehensive Reference, 10 Volume Set*, *4*, 779–831. https://doi.org/10.1016/B978-0-444-53349-4.00127-8

Zul, N. A., Ganesan, S., Hamidon, T. S., Oh, W. Da & Hussin, M. H. (2021). A review on the utilization of calcium oxide as a base catalyst in biodiesel production. *Journal of Environmental Chemical Engineering*, *9*(4), 105741. https://doi.org/10.1016/J.JECE.2021.105741