SYNTHESIS OF CALCIUM FERRITE PHOTOCATALYST FOR THE COD PHOTODEGRADATION OF PALM OIL MILL EFFLUENT UNDER VISIBLE LIGHT

ASHWIN CHARLES BENEDICT

DOCTOR OF PHILOSOPHY

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 Doctor of Philosophy.

____

(Supervisor's Signature)

Full Name : TS. DR. CHENG CHIN KUI

Position : ASSOCIATE PROFFESSOR

Date :

____

(Co-supervisor's Signature)

Full Name : DR. HAYDER A. ABDULBARI

Position : PROFESSOR

Date :

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 institutions.

____

(Student's Signature)

Full Name : ASHWIN CHARLES BENEDICT

ID Number : PKC15018

Date :

SYNTHESIS OF CALCIUM FERRITE PHOTOCATALYST FOR THE COD PHOTODEGRADATION OF PALM OIL MILL EFFLUENT UNDER VISIBLE LIGHT

ASHWIN CHARLES BENEDICT

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Doctor of Philosophy

Faculty of Chemical and Process Engineering Technology

UNIVERSITI MALAYSIA PAHANG

JANUARY 2020

ACKNOWLEDGEMENTS

This research would not be possible without the help and support of many individuals and organizations. I would like to extend my sincerest thanks to all of them. Foremost of these people is my main supervisor Associate Professor Dr. Cheng Chin Kui who has been an amazing role model and a constant motivator in helping me complete this PhD.

I am also highly indebted to Universiti Malaysia Pahang (UMP) for their financial support and providing me with the means and facilities to make this study possible. The lecturers and technical unit of this organization also deserve credit for being nothing if not professional and efficient.

Last but not least I would like to express my gratitude to mother Hazil Mirandah who has always been my greatest supporter as well as to my two sisters Evelyn Charles and Jocelyn Charles who have always believed in me even when I did not. Their endless love, support and encouragement have gotten me through the tough times.

ABSTRAK

Malaysia telah lama bergelut dengan isu pencemaran efluen kilang minyak sawit (POME) yang terbukti menjadi isu alam sekitar yang serius. Walaupun beberapa kajian untuk mengatasi masalah ini dengan menggunakan fotokatalis ZnO dan TiO_2 di bawah sinaran ultralembayung telah dilaksanakan, kajian tersebut masih ada ruang untuk penambahbaikan. Efisiensi cahaya rendah dan kecekapan photodegradation sederhana yang dihasilkan oleh dua sistem ini menonjolkan keperluan untuk fotokatalis yang diaktifkan oleh cahaya nampak yang dapat dilihat sebagai penyelesaian jangka panjang kepada masalah pencemaran alam yang disebabkan oleh POME. Tesis ini menghuraikan penggunaan $CaFe_2O_4$ sebagai fotokatalis yang diaktifkan oleh cahaya nampak untuk menangani masalah tersebut. Dua kaedah sintesis (pembakaran automatik dan permendakan bersama) dan dua suhu kalsinasi (550 °C dan 700 °C) digunakan untuk menghasilkan sejumlah empat pemangkin $CaFe_2O_4$ yang digelar AC550, AC700, CP550 dan CP700. CP550 mempamerkan penyingkiran COD terbesar sebanyak 69% pada kepekatan pemangkin 0.75 g/L selepas 8 jam irradiasi. Reaksi ini mematuhi kinetik urutan pertama dengan pemalar kadar 2.7 x 10-5 min^{-1}. Analisis BET menunjukkan bahawa CP550 mempunyai isipadu S_{BET} tertinggi (27.28 m^2/g) dan isipadu liang tertinggi (0.077 cm^3/g) antara semua fotokatalis yang diuji yang menurun secara mendadak bila suhu kalsinasi ditingkatkan untuk CP700 menyebabkan susutan S_{BET} kepada 9.73 m^2/g dan isipadu liang 0.025 cm^3/g disebabkan oleh penyepuhlindapan yang menyebabkan kawasan permukaan yang licin seperti yang dapat dilihat dalam imej SEM. UV-Vis DRS menunjukkan CP550 mempunyai luang jalur tertinggi (1.52 eV) yang mungkin disebabkan oleh kehadiran $CaFe_5O_7$ yang merupakan struktur unik $CaFe_2O_4$ yang mengandungi tiga unit FeO dalam fasa stabil seperti yang disimpulkan daripada data EDX dan disahkan oleh XRD. CP550 juga memaparkan spektrum PL paling rendah antara fotokatalis yang diuji menunjukkan kadar gabungan semula lubang-elektron yang rendah. Kajian hapus sisa menggunakan IPA menyebabkan kejatuhan COD yang mendadak dari 69% kepada hanya 7% menunjukkan radikal hidroksil sebagai spesies oksidatif reaktif utama. Kajian kitar semula menunjukkan bahawa penggunaan semula pemangkin yang terpakai menyebabkan penyusutan dari segi efisiensi degradasi COD dari 69.0% hingga 65.0% dan akhirnya 61.0% selepas tiga kitaran menunjukkan kehilangan aktiviti fotokatalitik. Pencirian pemangkin yang terpakai selepas proses fotokatalisis menunjukkan bahawa kehilangan aktiviti adalah disebabkan oleh pemendapan karbon seperti yang dibuktikan oleh data FTIR dan EDX. Penyelidikan ini memberi sumbangan kepada badan pengetahuan yang menangani isu fotokatalisis yang diaktifkan oleh cahaya nampak untuk pencegahan pencemar alam sekitar yang rekalsitran seperti POME.

ABSTRACT

Malaysia has long battled with the issue of palm oil mill effluent (POME) pollution which has proven to be detrimental to the environment. Although some attempts to alleviate this problem using ZnO and TiO_2 photocatalysts under ultra-violet irradiation have been undertaken, these have shown significant room for improvement. The low light utilization as well and mediocre photodegradation efficiency produced by these two systems highlight the need for a visible light driven photocatalyst as a long term solution to the problem. This thesis explores the application of $CaFe_2O_4$ as a visible light driven photocatalyst towards addressing that problem. Two synthesis routes namely the auto-combustion (AC) and co-precipitation (CP) routes and two calcination temperatures (550 °C and 700 °C) were used to produce a total of four $CaFe_2O_4$ catalysts namely AC550, AC700, CP550 and CP700. CP550 exhibited the greatest chemical oxygen demand (COD) degradation of 69% at a 0.75 g/L catalyst loading and an oxygen flow rate of 60 ml min^{-1} after 8 h of irradiation. The reaction adhered well to first order kinetics with a rate constant of 2.7 x 10^{-5} min^{-1}. Nitrogen physisorption studies indicated CP550 had the highest Brunauer-Emmett-Teller (BET) specific surface area (27.28 m^2/g) and pore volume (0.077 cm^3/g) of the prepared photocatalysts which dropped precipitously for CP700 upon increasing the calcination temperature to BET specific surface area of 9.73 m^2/g and pore volume of 0.025 cm^3/g due to annealing which created a smoother surface area as evidenced by the scanning electron microscope (SEM) images. Ultraviolet-visible diffuse reflectance spectroscopy (UV-Vis DRS) indicated CP550 had the highest band-gap (1.52 eV) which is likely due to the presence of $CaFe_5O_7$ which is a unique structure of $CaFe_2O_4$ containing three units of FeO in a stable phase as deduced from the energy dispersive X-ray microanalysis (EDX) data and confirmed by X-ray diffraction (XRD) peaks. CP550 also displayed the lowest photoluminescence (PL) spectra of the as prepared photocatalysts indicating a low electron-hole recombination rate. A scavenging study using iso-propyl alcohol (IPA) caused a severe drop in COD degradation from 69% to just 7% indicating hydroxyl radicals as the main reactive oxidative species. The recyclability study indicated that reusing the spent catalysts led to a decrease from 69.0% to 65.0% and finally 61.0% on subsequent cycles indicating some loss of activity over time. Post reaction characterization of the spent catalyst indicated that the loss of activity was due to carbon deposition as evidenced by FTIR and EDX data. This research contributes to the body of knowledge addressing the issue of visible light driven photocatalysis for the amelioration of recalcitrant environmental pollutants such as POME.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

c	characteristic constant of the adsorbate
λ	Wavelength (nm)
θ	Bragg's angle of incidence
β_{obs}	width at half maximum intensity
β_{inst}	standard instrumental line width
β_{d}	a true line width at half maximum intensity
α	photocatalyst coefficient
V_m	volume of gas adsorbed in correspondence to the monolayer coverage
t	adsorbed layer of thickness
r_K	Kelvin radius of the pore
r_{COD}	COD degradation rate in ppm min-1
P_a	ambient pressure
$OH^{\bullet}$	hydroxyl radical
$O^{2\bullet-}$	superoxide radical
k_{Sch}	Scherrer constant which assumes the numerical value of 0.93
K_A	adsorption equilibrium constant
hv	Incident light
H^+	protons
h^+	Photo-generated holes
g	photocatalyst mass
E_{bg}	Band gap energy
$d_{-spacings}$	inter-planar distances
D	crystalline size (nm)
C_{Ao}	initial COD concentration in the sample in ppm

LIST OF ABBREVIATIONS

AC	auto-combustion
AOPs	advanced oxidation processes
AV	accelerating voltage
BET	Brunauer-Emmett-Teller
BJH	Barrett, Joyner and Halenda analysis
BOD	Biochemical Oxygen Demand
BTSE	biologically treated secondary effluent
CB	conduction band
COD	Chemical Oxygen Demand
CP	co-precipitation
CPO	Crude Palm Oil
CSPO	Certified Sustainable Palm Oil
CSTR	continuous stirred tank reactors
DH	Dollimore and Heal analysis
DOE	Malaysia Department of Environment
DRS	Diffuse Reflectance Spectroscopy
E Coli	Escherichia coli
EDX	Energy Dispersive X-Ray Microanalysis
EFB	empty fruit bunch
EGSB	expanded granular sludge bed
EU	European Union
GHG	greenhouse gas
HEGM	hexane extractable gravimetric method
HRT	Hydraulic Retention Time
ICDD	International Centre for Diffraction Data
IPA	ispropyl alcohol
LH	Langmuir-Hinshelwood
LUMO	lowest unoccupied molecular orbital
MABB	modified anaerobic baffled bioreactor
MOF	metal organic framework
MSPO	Malaysian Sustainable Palm Oil

NGO	Non-Governmental Organization
O&G	Oil and Grease
OFAT	One Factor at a Time
OLR	organic loading rate
OPKS	oil palm kernel shells
PAC	polyaluminum chloride
PL	Photoluminescence Spectroscopy
POME	Palm Oil Mill Effluent
PTFE	polytetrafluoroethylene
ROS	reactive oxygen species
RSPO	Roundtable of Sustainable Palm Oil
SCS	solution combustion synthesis
SEM	Scanning Electron Microscopy
SKM	Schuster-Kubleka-Munk Model
SS	Suspended Solids
SSR	solid state reaction
TPA	terepthalic acid
TSS	Total Suspended Solids
UAMAS	ultrasonic-assisted membrane anaerobic systems
UASB	up-flow anaerobic sludge blanket
UASFF	up-flow anaerobic sludge fixed film
US	microwaves, ultrasonic
UV	ultra violet
VB	valence band
VFAs	volatile fatty acids
WWF	World Wildlife Foundation

REFERENCES

Aal, A. A., Barakat, M., & Mohamed, R. (2008). Electrophoreted Zn–TiO2–ZnO nanocomposite coating films for photocatalytic degradation of 2-chlorophenol. *Applied Surface Science, 254*(15), 4577-4583.

Abdel-Maksoud, Y., Imam, E., & Ramadan, A. (2016). TiO2 solar photocatalytic reactor systems: selection of reactor design for scale-up and commercialization—analytical review. *Catalysts, 6*(9), 138.

Abdi, F. F., Han, L., Smets, A. H., Zeman, M., Dam, B., & Van De Krol, R. (2013). Efficient solar water splitting by enhanced charge separation in a bismuth vanadate-silicon tandem photoelectrode. *Nature communications, 4*, 2195.

Abdullah, N., & Sulaiman, F. (2013). The oil palm wastes in Malaysia *Biomass now-sustainable growth and use*: IntechOpen.

Abdulrahman, N., & Azhari, N. (2013). Effect of organic loading rate on the performance of ultrasonic-assisted membrane anaerobic system (UAMAS) in treating palm oil mill effluent (POME). *Journal of American Science, 9 (9s): 23, 31*.

Abdurahman, N., Rosli, Y., & Azhari, N. (2013). The performance evaluation of anaerobic methods for Palm Oil Mill Effluent (POME) treatment: A review. *International perspectives on water quality management and pollutant control*, 88-106.

Abdurahman, N. H., & Azhari, N. H. (2016). An integrated UMAS for POME treatment. *Journal of Water Reuse and Desalination, 8*(1), 68-75. doi:10.2166/wrd.2016.124

Ahmad, A., Chong, M., Bhatia, S., & Ismail, S. (2006). Drinking water reclamation from palm oil mill effluent (POME) using membrane technology. *Desalination, 191*(1-3), 35-44.

Ahmad, A., Ismail, S., & Bhatia, S. (2005a). Membrane treatment for palm oil mill effluent: effect of transmembrane pressure and crossflow velocity. *Desalination, 179*(1-3), 245-255.

Ahmad, A., Ismail, S., & Bhatia, S. (2005b). Optimization of coagulation− flocculation process for palm oil mill effluent using response surface methodology. *Environmental science & technology, 39*(8), 2828-2834.

Ahmad, A., Sumathi, S., & Hameed, B. (2006). Coagulation of residue oil and suspended solid in palm oil mill effluent by chitosan, alum and PAC. *Chemical Engineering Journal, 118*(1-2), 99-105.

Al-Mamun, A., & Idris, A. (2008). Treatment of POME by pilot plant anaerobic fluidised bed reactor. *IIUM Engineering Journal, 9*(1), 9-18.

Alhaji, M. H., Sanaullah, K., Lim, S.-F., Khan, A., Hipolito, C. N., Abdullah, M. O., . . . Jamil, T. (2016). Photocatalytic treatment technology for palm oil mill effluent (POME)–A review. *Process Safety and Environmental Protection, 102*, 673-686.

Alvarez-Corena, J. R., Bergendahl, J. A., & Hart, F. L. (2016). Advanced oxidation of five contaminants in water by UV/TiO2: Reaction kinetics and byproducts identification. *Journal of Environmental Management, 181*, 544-551. doi:10.1016/j.jenvman.2016.07.015

Andreozzi, R., Caprio, V., Insola, A., & Marotta, R. (1999). Advanced oxidation processes (AOP) for water purification and recovery. *Catalysis Today, 53*(1), 51-59.

Arimi, A., Megatif, L., Granone, L. I., Dillert, R., & Bahnemann, D. W. (2018). Visible-light photocatalytic activity of zinc ferrites. *Journal of Photochemistry and Photobiology A: Chemistry*.

Aris, N. S. M., Ibrahim, S., Arifin, B., & Hawari, Y. (2017). Effect of operating parameters on decolourisation of palm oil mill effluent (POME) using electrocoagulation process. *Pertanika Journal of Science and Technology, 25*, 197-206.

Arshad, S., Aziz, A., Ngadi, N., & Amin, N. S. (2012). Phenol adsorption by activated carbon of different fiber size derived from empty fruit bunches. *J. Oil Palm Res, 24*, 1524-1532.

Asahi, R., Taga, Y., Mannstadt, W., & Freeman, A. J. (2000). Electronic and optical properties of anatase TiO 2. *Physical Review B, 61*(11), 7459.

Ayati, B., & Ganjidoust, H. (2006). Comparing the efficiency of UAFF and UASB with hybrid reactor in treating wood fiber wastewater. *Journal of Environmental Health Science & Engineering, 3*(1), 39-44.

Azmi, N. S., & Yunos, K. F. M. (2014). Wastewater treatment of palm oil mill effluent (POME) by ultrafiltration membrane separation technique coupled with adsorption treatment as pre-treatment. *Agriculture and Agricultural Science Procedia, 2*, 257-264.

Badiei, M., Jahim, J. M., Anuar, N., & Abdullah, S. R. S. (2011). Effect of hydraulic retention time on biohydrogen production from palm oil mill effluent in anaerobic sequencing batch reactor. *International Journal of Hydrogen Energy, 36*(10), 5912-5919.

Bai, X., Wang, L., Zong, R., Lv, Y., Sun, Y., & Zhu, Y. (2013). Performance enhancement of ZnO photocatalyst via synergic effect of surface oxygen defect and graphene hybridization. *Langmuir, 29*(9), 3097-3105. doi:10.1021/la4001768

Bakhsheshi-Rad, H. R., Hamzah, E., Low, H. T., Kasiri-Asgarani, M., Farahany, S., Akbari, E., & Cho, M. H. (2017). Fabrication of biodegradable Zn-Al-Mg alloy: Mechanical properties, corrosion behavior, cytotoxicity and antibacterial activities. *Materials Science and Engineering C, 73*, 215-219. doi:10.1016/j.msec.2016.11.138

Baranitharan, E., Khan, M. R., Prasad, D., & Salihon, J. B. (2013). Bioelectricity generation from palm oil mill effluent in microbial fuel cell using polacrylonitrile carbon felt as electrode. *Water, Air, & Soil Pollution, 224*(5), 1533.

Bashir, M. J., Mau Han, T., Jun Wei, L., Choon Aun, N., Amr, A., & Salem, S. (2016). Polishing of treated palm oil mill effluent (POME) from ponding system by electrocoagulation process. *Water Science and Technology, 73*(11), 2704-2712.

Basiron, Y. (2007). Palm oil production through sustainable plantations. *European Journal of Lipid Science and Technology, 109*(4), 289-295. doi:10.1002/ejlt.200600223

Bassi, P. S., Antony, R. P., Boix, P. P., Fang, Y., Barber, J., & Wong, L. H. (2016). Crystalline Fe2O3/Fe2TiO5 heterojunction nanorods with efficient charge separation and hole injection as photoanode for solar water oxidation. *Nano Energy, 22*, 310-318.

Bellaiche, L., Wei, S.-H., & Zunger, A. (1997). Band gaps of GaPN and GaAsN alloys. *Applied physics letters, 70*(26), 3558-3560.

Bhatia, D., Sharma, H., Meena, R. S., & Palkar, V. R. (2016). A novel ZnO piezoelectric microcantilever energy scavenger: Fabrication and characterization. *Sensing and Bio-Sensing Research, 9*, 45-52. doi:10.1016/j.sbsr.2016.05.008

Bhatia, S., Othman, Z., & Ahmad, A. L. (2007). Coagulation–flocculation process for POME treatment using Moringa oleifera seeds extract: optimization studies. *Chemical Engineering Journal, 133*(1-3), 205-212.

Borges, M. E., Sierra, M., Cuevas, E., García, R. D., & Esparza, P. (2016). Photocatalysis with solar energy: Sunlight-responsive photocatalyst based on TiO2 loaded on a natural material for wastewater treatment. *Solar Energy, 135*, 527-535. doi:10.1016/j.solener.2016.06.022

Borja, R., & Banks, C. (1994). Anaerobic digestion of palm oil mill effluent using an up-flow anaerobic sludge blanket reactor. *Biomass and Bioenergy, 6*(5), 381-389.

Borja, R., & Banks, C. J. (1994). Treatment of palm oil mill effluent by upflow anaerobic filtration. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental AND Clean Technology, 61*(2), 103-109.

Borja, R., & Banks, C. J. (1995). Comparison of an anaerobic filter and an anaerobic fluidized bed reactor treating palm oil mill effluent. *Process Biochemistry, 30*(6), 511-521.

Borja, R., Banks, C. J., & Sánchez, E. (1996). Anaerobic treatment of palm oil mill effluent in a two-stage up-flow anaerobic sludge blanket (UASB) system. *Journal of Biotechnology, 45*(2), 125-135.

Brunauer, S., Emmett, P. H., & Teller, E. (1938). Adsorption of gases in multimolecular layers. *Journal of the american chemical society, 60*(2), 309-319.

Byrne, C., Subramanian, G., & Pillai, S. C. (2018). Recent advances in photocatalysis for environmental applications. *Journal of Environmental Chemical Engineering, 6*(3), 3531-3555. doi:https://doi.org/10.1016/j.jece.2017.07.080

Carra, I., Sánchez Pérez, J. A., Malato, S., Autin, O., Jefferson, B., & Jarvis, P. (2016). Performance of different advanced oxidation processes for tertiary wastewater treatment to remove the pesticide acetamiprid. *Journal of Chemical Technology & Biotechnology, 91*(1), 72-81.

Carter, C., Finley, W., Fry, J., Jackson, D., & Willis, L. (2007). Palm oil markets and future supply. *European Journal of Lipid Science and Technology, 109*(4), 307-314. doi:10.1002/ejlt.200600256

Chan, K. S., & Chooi, C. (1983). *Ponding system for palm oil mill effluent treatment.* Paper presented at the Regional Workshop on Palm Oil Mill Technology and Effluent TreatmentAugust 1-2Kuala Lumpur.

Chan, Y. J., Tan, W. J. R., How, B. S., Lee, J. J., & Lau, V. Y. (2015). Fuzzy optimisation approach on the treatment of palm oil mill effluent (POME) via up-flow anaerobic sludge blanket–hollow centered packed bed (UASB–HCPB) reactor. *Journal of Water Process Engineering, 5*, 112-117.

Chen, M. J., Lo, S. L., Lee, Y. C., Kuo, J., & Wu, C. H. (2016). Decomposition of perfluorooctanoic acid by ultraviolet light irradiation with Pb-modified titanium dioxide. *Journal of hazardous materials, 303,* 111-118. doi:10.1016/j.jhazmat.2015.10.011

Cheng, C. K., Rizauddin Derahman, M., & Khan, M. R. (2015). Evaluation of the photocatalytic degradation of pre-treated palm oil mill effluent (POME) over Pt-loaded titania. *Journal of Environmental Chemical Engineering, 3*(1), 261-270. doi:https://doi.org/10.1016/j.jece.2014.10.016

Cheng, Y. W., Chang, Y. S., Ng, K. H., Wu, T. Y., & Cheng, C. K. (2017). Photocatalytic restoration of liquid effluent from oil palm agroindustry in Malaysia using tungsten oxides catalyst. *Journal of Cleaner Production, 162,* 205-219. doi:https://doi.org/10.1016/j.jclepro.2017.06.023

Chew, C. M., Aroua, M. K., Hussain, M. A., & Ismail, W. M. Z. W. (2016). Evaluation of ultrafiltration and conventional water treatment systems for sustainable development: an industrial scale case study. *Journal of Cleaner Production, 112*, 3152-3163.

Chin, M. J., Poh, P. E., Tey, B. T., Chan, E. S., & Chin, K. L. (2013). Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective. *Renewable and Sustainable Energy Reviews, 26*, 717-726. doi:https://doi.org/10.1016/j.rser.2013.06.008

Choi, W., Termin, A., & Hoffmann, M. R. (1994). The role of metal ion dopants in quantum-sized TiO2: correlation between photoreactivity and charge carrier recombination dynamics. *The Journal of Physical Chemistry, 98*(51), 13669-13679.

Chong, M. N., Jin, B., Chow, C. W. K., & Saint, C. (2010). Recent developments in photocatalytic water treatment technology: A review. *Water research, 44*(10), 2997-3027. doi:10.1016/j.watres.2010.02.039

Choong, Y. Y., Chou, K. W., & Norli, I. (2018). Strategies for improving biogas production of palm oil mill effluent (POME) anaerobic digestion: A critical review. *Renewable and Sustainable Energy Reviews*, *82*, 2993-3006.

Comninellis, C., Kapalka, A., Malato, S., Parsons, S. A., Poulios, I., & Mantzavinos, D. (2008). Advanced oxidation processes for water treatment: advances and trends for R&D. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology, 83*(6), 769-776.

Cui, Y., Briscoe, J., & Dunn, S. (2013). Effect of ferroelectricity on solar-light-driven photocatalytic activity of BaTiO3 - Influence on the carrier separation and stern layer formation. *Chemistry of Materials, 25*(21), 4215-4223. doi:10.1021/cm402092f

Cullity, B. D., & Stock, S. R. (2001). *Elements of X-ray Diffraction* (Vol. 3): Prentice hall New Jersey.

Dai, Y.-M., Lu, C.-Y., & Pan, Y.-T. (2016). Evaluating the photocatalytic activity of Pt/TNT film catalyst. *Ceramics International, 42*(7), 7993-7999. doi:10.1016/j.ceramint.2016.01.201

Delacotte, C., Bréard, Y., Caignaert, V., Hardy, V., Greneche, J. M., Hébert, S., . . . Pelloquin, D. (2017). Morin-like spin canting in the magnetic CaFe5O7 ferrite: A combined neutron and Mössbauer study. *Journal of Solid State Chemistry, 247*, 13-19. doi:https://doi.org/10.1016/j.jssc.2016.12.021

Delacotte, C., Hébert, S., Hardy, V., Bréard, Y., Maki, R., Mori, T., & Pelloquin, D. (2016). Impact of densification on microstructure and transport properties of CaFe5O7. *Solid State Sciences, 54*, 54-58. doi:https://doi.org/10.1016/j.solidstatesciences.2015.11.006

Delacotte, C., Hüe, F., Bréard, Y., Hébert, S., Pérez, O., Caignaert, V., . . . Pelloquin, D. (2014). Structural Transition at 360 K in the CaFe5O7 Ferrite: Toward a New Charge Ordering Distribution. *Inorganic Chemistry, 53*(19), 10171-10177. doi:10.1021/ic5011456

Delacotte, C., Monnier, L., Bréard, Y., Hébert, S., & Pelloquin, D. (2016). *Order/disorder mechanisms in complex (CaFe2O4)(FeO) n ferrites (n= 1, 3).* Paper presented at the European Microscopy Congress 2016: Proceedings.

Demircivi, P., & Simsek, E. B. (2019). Visible-light-enhanced photoactivity of perovskite-type W-doped BaTiO3 photocatalyst for photodegradation of tetracycline. *Journal of Alloys and Compounds, 774*, 795-802. doi:https://doi.org/10.1016/j.jallcom.2018.09.354

Deng, Y., & Zhao, R. (2015). Advanced Oxidation Processes (AOPs) in Wastewater Treatment. *Current Pollution Reports, 1*(3), 167-176. doi:10.1007/s40726-015-0015-z

Dewil, R., Mantzavinos, D., Poulios, I., & Rodrigo, M. A. (2017). New perspectives for Advanced Oxidation Processes. *Journal of Environmental Management, 195*, 93-99. doi:https://doi.org/10.1016/j.jenvman.2017.04.010

Di Valentin, C., & Pacchioni, G. (2013). Trends in non-metal doping of anatase TiO2: B, C, N and F. *Catalysis Today, 206*, 12-18.

Domen, K., Ebina, Y., Sekine, T., Tanaka, A., Kondo, J., & Hirose, C. (1993). Ion-exchangeable layered niobates as photocatalysts. *Catalysis Today, 16*(3-4), 479-486.

Donald, P. F. (2004). Biodiversity impacts of some agricultural commodity production systems. *Conservation Biology, 18*(1), 17-38.

El-Rafei, A., El-Kalliny, A. S., & Gad-Allah, T. A. (2017). Electrospun magnetically separable calcium ferrite nanofibers for photocatalytic water purification. *Journal of Magnetism and Magnetic Materials, 428*, 92-98.

Faisal, M., & Unno, H. (2001). Kinetic analysis of palm oil mill wastewater treatment by a modified anaerobic baffled reactor. *Biochemical Engineering Journal, 9*(1), 25-31.

Fang, C., O-Thong, S., Boe, K., & Angelidaki, I. (2011). Comparison of UASB and EGSB reactors performance, for treatment of raw and deoiled palm oil mill effluent (POME). *Journal of hazardous materials, 189*(1), 229-234. doi:https://doi.org/10.1016/j.jhazmat.2011.02.025

Foo, K., & Hameed, B. (2011). Microwave-assisted preparation of oil palm fiber activated carbon for methylene blue adsorption. *Chemical Engineering Journal, 166*(2), 792-795.

Frei, R. (1976). *Diffuse reflectance spectroscopy; applications, standards, and calibration (with special reference to chromatography).* Paper presented at the Standardization in Spectrophotometry and Luminescence Measurements: Proceedings of a Workshop Seminar Held at the National Bureau of Standards, Gaithersburg, Maryland, November, November 19-20, 1975.

Fuentes, L., & Reyes, M. (2002). Difracción de rayos X. *Mineralogía analítica. Dirección de extensión y difusión cultural. Chihuahua, México*, 204-205.

Fujishima, A., & Honda, K. (1972). Electrochemical photolysis of water at a semiconductor electrode. *nature, 238*(5358), 37.

Gayathri, P. V., Yesodharan, S., & Yesodharan, E. P. (2019). Microwave/Persulphate assisted ZnO mediated photocatalysis (MW/PS/UV/ZnO) as an efficient advanced oxidation process for the removal of RhB dye pollutant from water. *Journal of Environmental Chemical Engineering, 7*(4), 103122. doi:https://doi.org/10.1016/j.jece.2019.103122

George, R., Bahadur, N., Singh, N., Singh, R., Verma, A., & Shukla, A. K. (2016). *Environmentally Benign TiO2 Nanomaterials for Removal of Heavy Metal Ions with Interfering Ions Present in Tap Water*. Paper presented at the Materials Today: Proceedings.

Gerardi, M. H. (2003). *The microbiology of anaerobic digesters*: John Wiley & Sons.

Glaze, W. H. (1987). Drinking-water treatment with ozone. *Environmental science & technology, 21*(3), 224-230.

Glaze, W. H., Kang, J.-W., & Chapin, D. H. (1987). The chemistry of water treatment processes involving ozone, hydrogen peroxide and ultraviolet radiation.

Gligorovski, S., Strekowski, R., Barbati, S., & Vione, D. (2015). Environmental implications of hydroxyl radicals (• OH). *Chemical Reviews, 115*(24), 13051-13092.

Gmurek, M., Olak-Kucharczyk, M., & Ledakowicz, S. (2017). Photochemical decomposition of endocrine disrupting compounds – A review. *Chemical Engineering Journal, 310*, 437-456. doi:10.1016/j.cej.2016.05.014

Grady Jr, C. L., Daigger, G. T., Love, N. G., & Filipe, C. D. (2011). *Biological wastewater treatment*: CRC press.

Guan, M., Xiao, C., Zhang, J., Fan, S., An, R., Cheng, Q., . . . Xie, Y. (2013). Vacancy associates promoting solar-driven photocatalytic activity of ultrathin bismuth oxychloride nanosheets. *Journal of the american chemical society, 135*(28), 10411-10417. doi:10.1021/ja402956f

Hamdi, M., & Garcia, J.-L. (1991). Comparison between anaerobic filter and anaerobic contact process for fermented olive mill wastewaters. *Bioresource technology, 38*(1), 23-29.

Hamilton, J. W. J., Byrne, J. A., Dunlop, P. S. M., Dionysiou, D. D., Pelaez, M., O'Shea, K., . . . Pillai, S. C. (2014). Evaluating the mechanism of visible light activity for N,F-TiO 2 using photoelectrochemistry. *Journal of Physical Chemistry C, 118*(23), 12206-12215. doi:10.1021/jp4120964

Hanaor, D. A., Ghadiri, M., Chrzanowski, W., & Gan, Y. (2014). Scalable surface area characterization by electrokinetic analysis of complex anion adsorption. *Langmuir, 30*(50), 15143-15152.

Hanley, C., Layne, J., Punnoose, A., Reddy, K., Coombs, I., Coombs, A., . . . Wingett, D. (2008). Preferential killing of cancer cells and activated human T cells using ZnO nanoparticles. *Nanotechnology, 19*(29), 295103.

Hasanudin, U., Sugiharto, R., Haryanto, A., Setiadi, T., & Fujie, K. (2015). Palm oil mill effluent treatment and utilization to ensure the sustainability of palm oil industries. *Water Science and Technology, 72*(7), 1089-1095. doi:10.2166/wst.2015.311

Hassan, M. A., Yacob, S., Shirai, Y., & Hung, Y.-T. (2005). Treatment of palm oil wastewaters. *Waste Treatment in the Food Processing Industry*, 101-102.

Hernández-Carrillo, M. A., Torres-Ricárdez, R., García-Mendoza, M. F., Ramírez-Morales, E., Rojas-Blanco, L., Díaz-Flores, L. L., . . . Pérez-Hernández, G. (2018). Eu-modified ZnO nanoparticles for applications in photocatalysis. *Catalysis Today*. doi:https://doi.org/10.1016/j.cattod.2018.04.060

Ho, C., Tan, Y., & Wang, C. (1984). The distribution of chemical constituents between the soluble and the particulate fractions of palm oil mill effluent and its significance on its utilisation/treatment. *Agricultural Wastes, 11*(1), 61-71.

Hu, Y., Li, D., Wang, H., Zeng, G., Li, X., & Shao, Y. (2015). Role of active oxygen species in the liquid-phase photocatalytic degradation of RhB using BiVO4/TiO2 heterostructure under visible light irradiation. *Journal of Molecular Catalysis A: Chemical, 408*, 172-178. doi:https://doi.org/10.1016/j.molcata.2015.07.025

Huang, N., Shu, J., Wang, Z., Chen, M., Ren, C., & Zhang, W. (2015). One-step pyrolytic synthesis of ZnO nanorods with enhanced photocatalytic activity and high photostability under visible light and UV light irradiation. *Journal of Alloys and Compounds, 648*, 919-929. doi:10.1016/j.jallcom.2015.07.039

Ibhadon, A., & Fitzpatrick, P. (2013). Heterogeneous photocatalysis: recent advances and applications. *Catalysts, 3*(1), 189-218.

Ibrahim, A., Yeoh, B., Cheah, S., Ma, A., Ahmad, S., Chew, T., . . . Wahid, M. J. (1985). Thermophilic anaerobic contact digestion of palm oil mill effluent. *Water Science and Technology, 17*(2-3), 155-166.

Ibrahim, I., Hassan, M. A., Abd-Aziz, S., Shirai, Y., Andou, Y., Othman, M. R., . . . Zakaria, M. R. (2017). Reduction of residual pollutants from biologically treated palm oil mill effluent final discharge by steam activated bioadsorbent from oil palm biomass. *Journal of Cleaner Production, 141*, 122-127.

Idris, M., Jami, M. S., & Muyibi, S. A. (2010). Tertiary treatment of biologically treated palm oil mill effluent (POME) using UF membrane system: effect of MWCO and transmembrane pressure. *International Journal, 1*(2).

Igwe, J., & Onyegbado, C. (2007). A review of palm oil mill effluent (POME) water treatment. *Global Journal of Environmental Research, 1*(2), 54-62.

Ishikawa, Y., & Matsumoto, Y. (2001). Electrodeposition of TiO2 photocatalyst into nano-pores of hard alumite. *Electrochimica Acta, 46*(18), 2819-2824.

Iskandar, M. J., Baharum, A., Anuar, F. H., & Othaman, R. (2018). Palm oil industry in South East Asia and the effluent treatment technology—A review. *Environmental Technology & Innovation, 9*, 169-185. doi:https://doi.org/10.1016/j.eti.2017.11.003

Iwase, A., Kato, H., & Kudo, A. (2006). Nanosized Au particles as an efficient cocatalyst for photocatalytic overall water splitting. *Catalysis letters, 108*(1-2), 7-10.

Jalani, N. F., Aziz, A. A., Wahab, N. A., Hassan, W. H. W., & Zainal, N. H. (2016). Application of palm kernel shell activated carbon for the removal of pollutant and color in palm oil mill effluent treatment. *Journal of Earth, Environment and Health Sciences, 2*(1), 15.

Jiang, J., Zhao, K., Xiao, X., & Zhang, L. (2012). Synthesis and facet-dependent photoreactivity of BiOCl single-crystalline nanosheets. *Journal of the american chemical society, 134*(10), 4473-4476. doi:10.1021/ja210484t

Julaidi, R. (2014). Regulatory requirements for biogas plants, effluent discharge and flue gas emissions for palm oil mill. . *Paper presented at the Seminar on Palm Oil Mill, Refinery, Environmental and Quality. Pullman Hotel, Kuching, Sarawak, Malaysia.*

Kalarivalappil, V., Divya, C. M., Wunderlich, W., Pillai, S. C., Hinder, S. J., Nageri, M., . . . Vijayan, B. K. (2016). Pd Loaded TiO2 Nanotubes for the Effective Catalytic Reduction of p-Nitrophenol. *Catalysis letters, 146*(2), 474-482. doi:10.1007/s10562-015-1663-8

Kalyuzhnyi, S., de los Santos, L. E., & Martinez, J. R. (1998). Anaerobic treatment of raw and preclarified potato-maize wastewaters in a USAB reactor. *Bioresource technology, 66*(3), 195-199.

Kamegawa, T., Shimizu, Y., & Yamashita, H. (2012). Superhydrophobic surfaces with photocatalytic self- cleaning properties by nanocomposite coating of TiO2 and polytetrafluoroethylene. *Advanced Materials, 24*(27), 3697-3700.

Kamyab, H., Chelliapan, S., Din, M. F. M., Rezania, S., Khademi, T., & Kumar, A. (2018). Palm Oil Mill Effluent as an Environmental Pollutant. *Palm Oil*, 13.

Kang, Y. W., Cho, M.-J., & Hwang, K.-Y. (1999). Correction of hydrogen peroxide interference on standard chemical oxygen demand test. *Water Research, 33*(5), 1247-1251. doi:https://doi.org/10.1016/S0043-1354(98)00315-7

Kappadan, S., Gebreab, T. W., Thomas, S., & Kalarikkal, N. (2016). Tetragonal BaTiO3 nanoparticles: An efficient photocatalyst for the degradation of organic pollutants. *Materials Science in Semiconductor Processing, 51*, 42-47. doi:https://doi.org/10.1016/j.mssp.2016.04.019

Kayaalp, N., Ersahin, M. E., Ozgun, H., Koyuncu, I., & Kinaci, C. (2010). A new approach for chemical oxygen demand (COD) measurement at high salinity and low organic matter samples. *Environmental Science and Pollution Research, 17*(9), 1547-1552.

Khalid, A. R., & Mustafa, W. A. W. (1992). External benefits of environmental regulation: Resource recovery and the utilisation of effluents. *Environmentalist, 12*(4), 277-285. doi:10.1007/BF01267698

Khanna, L., & Verma, N. K. (2013). PEG/CaFe2O4 nanocomposite: Structural, morphological, magnetic and thermal analyses. *Physica B: Condensed Matter, 427*, 68-75. doi:https://doi.org/10.1016/j.physb.2013.05.040

Khemkhao, M., Nuntakumjorn, B., Techkarnjanaruk, S., & Phalakornkule, C. (2011). Effect of chitosan on UASB treating POME during a transition from mesophilic to thermophilic conditions. *Bioresource technology, 102*(7), 4674-4681.

Khemkhao, M., Techkarnjanaruk, S., & Phalakornkule, C. (2016). Effect of chitosan on reactor performance and population of specific methanogens in a modified CSTR treating raw POME. *Biomass and Bioenergy, 86*, 11-20.

Kim, B. R. (1989). Effect of ammonia on COD analysis. *Journal (Water Pollution Control Federation)*, 614-617.

Klöpffer, W. (1996). Environmental hazard assessment of chemicals and products. Part V. Anthropogenic chemicals in sewage sludge. *Chemosphere, 33*(6), 1067-1081.

Klug, H. P., & Alexander, L. E. (1974). X-ray diffraction procedures: for polycrystalline and amorphous materials. *X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition, by Harold P. Klug, Leroy E. Alexander, pp. 992. ISBN 0-471-49369-4. Wiley-VCH, May 1974.*, 992.

Lal, G., Punia, K., Dolia, S. N., Alvi, P. A., Dalela, S., & Kumar, S. (2019). Rietveld refinement, Raman, optical, dielectric, Mössbauer and magnetic characterization of superparamagnetic fcc-CaFe2O4 nanoparticles. *Ceramics International, 45*(5), 5837-5847. doi:https://doi.org/10.1016/j.ceramint.2018.12.050

Laurance, W. F., Koh, L. P., Butler, R., Sodhi, N. S., Bradshaw, C. J. A., Neidel, J. D., . . . Mateo Vega, J. (2010). Improving the Performance of the Roundtable on Sustainable Palm Oil for Nature Conservation. *Conservation Biology, 24*(2), 377-381. doi:doi:10.1111/j.1523-1739.2010.01448.x

Lawrence, K., Wang, J., Stephen, T., & Yung-Tse, H. (2010). Handbook of environmental engineering, environmental bioengineering: Springer, New York.

Lawrence, M., & Jiang, Y. (2017). Porosity, pore size distribution, micro-structure *Bio-aggregates Based Building Materials* (pp. 39-71): Springer.

Lee, Z. S., Chin, S. Y., Lim, J. W., Witoon, T., & Cheng, C. K. (2019). Treatment technologies of palm oil mill effluent (POME) and olive mill wastewater (OMW): A brief review. *Environmental Technology & Innovation, 15*, 100377. doi:https://doi.org/10.1016/j.eti.2019.100377

Lees, E., Noble, B., Hewitt, R., & Parsons, S. (2001). The impact of residual coagulant on the respiration rate and sludge characteristics of an activated microbial biomass. *Process Safety and Environmental Protection, 79*(5), 283-290.

Lettinga, G. (1995). Anaerobic digestion and wastewater treatment systems. *Antonie van leeuwenhoek, 67*(1), 3-28.

Li, K., Tang, Y., Xu, Y., Wang, Y., Huo, Y., Li, H., & Jia, J. (2013). A BiOCl film synthesis from Bi2O3 film and its UV and visible light photocatalytic activity. *Applied Catalysis B: Environmental, 140*, 179-188.

Liew, W. L., Kassim, M. A., Muda, K., Loh, S. K., & Affam, A. C. (2015). Conventional methods and emerging wastewater polishing technologies for palm oil mill effluent treatment: a review. *Journal of Environmental Management, 149*, 222-235.

Lightcap, I. V., Kosel, T. H., & Kamat, P. V. (2010). Anchoring semiconductor and metal nanoparticles on a two-dimensional catalyst mat. Storing and shuttling electrons with reduced graphene oxide. *Nano letters, 10*(2), 577-583.

Liu, J., Wang, Y., Ma, J., Peng, Y., & Wang, A. (2019). A review on bidirectional analogies between the photocatalysis and antibacterial properties of ZnO. *Journal of Alloys and Compounds, 783*, 898-918. doi:https://doi.org/10.1016/j.jallcom.2018.12.330

Liu, X., Zhang, Y., Jia, Y., Jiang, J., Wang, Y., Chen, X., & Gui, T. (2017). Visible light-responsive carbon-decorated p-type semiconductor CaFe2O4 nanorod photocatalyst for efficient remediation of organic pollutants. *Chinese Journal of Catalysis, 38*(10), 1770-1779.

Lorestani, A. A. Z. (2006). *Biological treatment of palm oil effluent (POME) using an up-flow anaerobic sludge fixed film (UASFF) bioreactor [TD899. P4 L869 2006 f rb]*. Universiti Sains Malaysia.

Lu, Y., Li, Y., Qin, L., Huang, Y., Qin, C., Tsuboi, T., & Huang, W. (2015). Efficient conversion from UV light to near-IR emission in Yb3+-doped triple-layered perovskite CaLaNb3O10. *Materials Research Bulletin, 64*, 425-431.

Luo, D., & Kang, Y. (2018). Synthesis and characterization of novel CaFe2O4/Bi2O3 composite photocatalysts. *Materials Letters, 225*, 17-20.

Lüth, H., & Ibach, H. (2003). *Solid-state physics: an introduction to principles of materials science*: Springer-Verlag Berlin Heidelberg.

Ma, A. N. (1999). Innovations in management of palm oil mill effluent. *Planter (Malaysia).*

Manickam, S., Parthasarathy, S., Alzorqi, I., Ng, E. H., Tiong, T. J., Gomes, R. L., & Ali, A. (2014). Role of H2O2 in the fluctuating patterns of COD (chemical oxygen demand) during the treatment of palm oil mill effluent (POME) using pilot scale triple frequency ultrasound cavitation reactor. *Ultrasonics sonochemistry, 21*(4), 1519-1526.

Marschall, R. (2014). Semiconductor composites: strategies for enhancing charge carrier separation to improve photocatalytic activity. *Advanced Functional Materials, 24*(17), 2421-2440.

Masoomi, M. Y., Bagheri, M., Morsali, A., & Junk, P. C. (2016). High photodegradation efficiency of phenol by mixed-metal-organic frameworks. *Inorganic Chemistry Frontiers, 3*(7), 944-951. doi:10.1039/c6qi00067c

Mboula, V. M., Héquet, V., Andrès, Y., Gru, Y., Colin, R., Doña-Rodríguez, J. M., . . . Falaras, P. (2015). Photocatalytic degradation of estradiol under simulated solar light and assessment of estrogenic activity. *Applied Catalysis B: Environmental, 162*, 437-444. doi:10.1016/j.apcatb.2014.05.026

Minero, C., Mariella, G., Maurino, V., & Pelizzetti, E. (2000). Photocatalytic transformation of organic compounds in the presence of inorganic anions. 1. Hydroxyl-mediated and direct electron-transfer reactions of phenol on a titanium dioxide− fluoride system. *Langmuir, 16*(6), 2632-2641.

Miranda-García, N., Suárez, S., Sánchez, B., Coronado, J. M., Malato, S., & Maldonado, M. I. (2011). Photocatalytic degradation of emerging contaminants in municipal wastewater treatment plant effluents using immobilized TiO 2 in a solar pilot plant. *Applied Catalysis B: Environmental, 103*(3-4), 294-301. doi:10.1016/j.apcatb.2011.01.030

Mohajan, H. (2011). Dangerous effects of methane gas in atmosphere.

Molinari, R., Lavorato, C., & Argurio, P. (2017). Recent progress of photocatalytic membrane reactors in water treatment and in synthesis of organic compounds. A review. *Catalysis Today, 281*, 144-164. doi:10.1016/j.cattod.2016.06.047

Mor, G. K., Shankar, K., Paulose, M., Varghese, O. K., & Grimes, C. A. (2006). Use of highly-ordered TiO2 nanotube arrays in dye-sensitized solar cells. *Nano letters, 6*(2), 215-218.

Mukherjee, I., & Sovacool, B. K. (2014). Palm oil-based biofuels and sustainability in southeast Asia: A review of Indonesia, Malaysia, and Thailand. *Renewable and Sustainable Energy Reviews, 37*, 1-12.

Mun, Y. W. (2012). Production of Methane from Palm Oil Mill Effluent by Using Ultrasonicated Membrane Anaerobic System (UMAS).

Mundi, I. (2017). Indonesia Palm Oil Production by Year http://www. indexmundi. com/agriculture/? country= id&commodity= palm-oil&graph= production: Retrieved.

Murgolo, S., Yargeau, V., Gerbasi, R., Visentin, F., El Habra, N., Ricco, G., . . . Mascolo, G. (2017). A new supported TiO2 film deposited on stainless steel for the photocatalytic degradation of contaminants of emerging concern. *Chemical Engineering Journal, 318*, 103-111.

Naderi, M. (2015). Surface Area: Brunauer–Emmett–Teller (BET) *Progress in filtration and separation* (pp. 585-608): Elsevier.

Nair, S., Sasidharan, A., Rani, V. D., Menon, D., Nair, S., Manzoor, K., & Raina, S. (2009). Role of size scale of ZnO nanoparticles and microparticles on toxicity toward bacteria and osteoblast cancer cells. *Journal of Materials Science: Materials in Medicine, 20*(1), 235.

Najafpour, G., Zinatizadeh, A., Mohamed, A., Isa, M. H., & Nasrollahzadeh, H. (2006). High-rate anaerobic digestion of palm oil mill effluent in an upflow anaerobic sludge-fixed film bioreactor. *Process Biochemistry, 41*(2), 370-379.

Ng, I. (2017). The Impacts of Logging and Palm Oil on Aquatic Ecosystems and Freshwater Sources in Southeast Asia. *EnviroLab Asia, 1*(3), 3.

Ng, K. H. (2017). *An Application of Advanced Oxidation Process to Photopolish Palm Oil MIll Effluent over TiO_2 and ZnO Photocatalysts.* (PhD), Universiti Malaysia Pahang, Malaysia.

Ng, K. H., & Cheng, C. K. (2015). A novel photomineralization of POME over UV-responsive TiO 2 photocatalyst: kinetics of POME degradation and gaseous product formations. *RSC Advances, 5*(65), 53100-53110.

Ng, K. H., & Cheng, C. K. (2016). Photo-polishing of POME into CH4-lean biogas over the UV-responsive ZnO photocatalyst. *Chemical Engineering Journal, 300*, 127-138. doi:https://doi.org/10.1016/j.cej.2016.04.105

Ng, K. H., Cheng, Y. W., Khan, M. R., & Cheng, C. K. (2016). Optimization of photocatalytic degradation of palm oil mill effluent in UV/ZnO system based on response surface methodology. *Journal of Environmental Management, 184*, 487-493. doi:https://doi.org/10.1016/j.jenvman.2016.10.034

Ng, K. H., Khan, M. R., Ng, Y. H., Hossain, S. S., & Cheng, C. K. (2017). Restoration of liquid effluent from oil palm agroindustry in Malaysia using UV/TiO2 and UV/ZnO photocatalytic systems: A comparative study. *Journal of Environmental Management, 196*, 674-680. doi:https://doi.org/10.1016/j.jenvman.2017.03.078

Ng, K. H., Lee, C. H., Khan, M. R., & Cheng, C. K. (2016). Photocatalytic degradation of recalcitrant POME waste by using silver doped titania: Photokinetics and scavenging studies. *Chemical Engineering Journal, 286*, 282-290. doi:https://doi.org/10.1016/j.cej.2015.10.072

Ng, W., Goh, A. C., & Tay, J. (1987). Palm oil mill effluent (POME) treatment—an assessment of coagulants used to aid liquid-solid separation. *Biological Wastes, 21*(4), 237-248.

O'regan, B., & Grätzel, M. (1991). A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO2 films. *nature, 353*(6346), 737.

Ohimain, E. I., & Izah, S. C. (2017). A review of biogas production from palm oil mill effluents using different configurations of bioreactors. *Renewable and Sustainable Energy Reviews, 70*, 242-253.

Ohno, T., Murakami, N., Tsubota, T., & Nishimura, H. (2008). Development of metal cation compound-loaded S-doped TiO2 photocatalysts having a rutile phase under visible light. *Applied Catalysis A: General, 349*(1-2), 70-75.

Ostrovsky, S., Kazimirsky, G., Gedanken, A., & Brodie, C. (2009). Selective cytotoxic effect of ZnO nanoparticles on glioma cells. *Nano Research, 2*(11), 882-890. doi:10.1007/s12274-009-9089-5

Othman, M. R., Hassan, M. A., Shirai, Y., Baharuddin, A. S., Ali, A. A. M., & Idris, J. (2014). Treatment of effluents from palm oil mill process to achieve river water quality for reuse as recycled water in a zero emission system. *Journal of Cleaner Production, 67*, 58-61.

Panchangam, S. C., Yellatur, C. S., Yang, J. S., Loka, S. S., Lin, A. Y. C., & Vemula, V. (2018). Facile fabrication of TiO2-graphene nanocomposites (TGNCs) for the efficient photocatalytic oxidation of perfluorooctanoic acid (PFOA). *Journal of Environmental Chemical Engineering, 6*(5), 6359-6369. doi:10.1016/j.jece.2018.10.003

Park, D.-R., Zhang, J., Ikeue, K., Yamashita, H., & Anpo, M. (1999). Photocatalytic oxidation of ethylene to CO2 and H2O on ultrafine powdered TiO2 photocatalysts in the presence of O2 and H2O. *Journal of Catalysis, 185*(1), 114-119.

Park, H.-J., Kim, J. Y., Kim, J., Lee, J.-H., Hahn, J.-S., Gu, M. B., & Yoon, J. (2009). Silver-ion-mediated reactive oxygen species generation affecting bactericidal activity. *Water research, 43*(4), 1027-1032.

Parthasarathy, S., Mohammed, R. R., Fong, C. M., Gomes, R. L., & Manickam, S. (2016). A novel hybrid approach of activated carbon and ultrasound cavitation for the intensification of palm oil mill effluent (POME) polishing. *Journal of Cleaner Production, 112*, 1218-1226.

Pei, L., Liu, H., Lin, N., & Yu, H. (2015). Bismuth titanate nanorods and their visible light photocatalytic properties. *Journal of Alloys and Compounds, 622*, 254-261.

Pelaez, M., Nolan, N. T., Pillai, S. C., Seery, M. K., Falaras, P., Kontos, A. G., . . . O'shea, K. (2012). A review on the visible light active titanium dioxide photocatalysts for environmental applications. *Applied Catalysis B: Environmental, 125*, 331-349.

Pennington, A. M. (2015). *Increased visible-light photocatalytic activity of TiO2 via band gap manipulation.* Rutgers University-Graduate School-New Brunswick.

Philippe, K. K., Timmers, R., Van Grieken, R., & Marugan, J. (2016). Photocatalytic Disinfection and Removal of Emerging Pollutants from Effluents of Biological Wastewater Treatments, Using a Newly Developed Large-Scale Solar Simulator. *Industrial and Engineering Chemistry Research, 55*(11), 2952-2958. doi:10.1021/acs.iecr.5b04927

Philips‐ Invernizzi, B., Dupont, D., & Caze, C. (2002). Formulation of colored fiber blends from Friele's theoretical model. *Color Research & Application: Endorsed by Inter‐ Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur, 27*(3), 191-198.

Pleanjai, S., Gheewala, S. H., & Garivait, S. (2007). Environmental evaluation of biodiesel production from palm oil in a life cycle perspective. *Asian J. Energy Environ, 8*(1), 15-32.

Poh, P. E., & Chong, M. F. (2009). Development of anaerobic digestion methods for palm oil mill effluent (POME) treatment. *Bioresource technology, 100*(1), 1-9. doi:https://doi.org/10.1016/j.biortech.2008.06.022

Reijnders, L., & Huijbregts, M. (2008). Palm oil and the emission of carbon-based greenhouse gases. *Journal of cleaner production, 16*(4), 477-482.

Rengifo-Herrera, J. A., & Pulgarin, C. (2010). Photocatalytic activity of N, S co-doped and N-doped commercial anatase TiO2 powders towards phenol oxidation and E. coli inactivation under simulated solar light irradiation. *Solar Energy, 84*(1), 37-43. doi:10.1016/j.solener.2009.09.008

Richtberg, S., & Girwidz, R. (2016). Wirkungen multimedialer Einblendungen beim Experimentieren am Computer. *PhyDid B-Didaktik der Physik-Beiträge zur DPG-Frühjahrstagung*.

Roonasi, P., & Mazinani, M. (2017). Synthesis and application of barium ferrite/activated carbon composite as an effective solar photocatalyst for discoloration of organic dye contaminants in wastewater. *Journal of Environmental Chemical Engineering, 5*(4), 3822-3827.

Rouquerol, J., Llewellyn, P., & Rouquerol, F. (2007). Is the BET equation applicable to microporous adsorbents. *Stud. Surf. Sci. Catal, 160*(07), 49-56.

RSPO. (2009). Proceedings of the 6th roundtable meeting on sustainable palm oil. . *RSPO (Roundtable on Sustainable Palm Oil), Selnagor, Malaysia*.

RSPO. (2015). Impact Update.

Rugayah, A., Astimar, A., & Norzita, N. (2014). Preparation and characterization of activated carbon from palm kernel shell by physical activation with steam. *JOURNAL OF OIL PALM RESEARCH, 26*(3), 251-264.

Rupani, P. F., Singh, R. P., Ibrahim, M. H., & Esa, N. (2010). Review of current palm oil mill effluent (POME) treatment methods: vermicomposting as a sustainable practice. *World Applied Sciences Journal, 11*(1), 70-81.

Ruysschaert, D., & Salles, D. (2014). Towards global voluntary standards: Questioning the effectiveness in attaining conservation goals: The case of the Roundtable on Sustainable Palm Oil (RSPO). *Ecological Economics, 107*, 438-446. doi:https://doi.org/10.1016/j.ecolecon.2014.09.016

Saeed, M. O., Azizli, K., Isa, M. H., & Bashir, M. J. (2015). Application of CCD in RSM to obtain optimize treatment of POME using Fenton oxidation process. *Journal of Water Process Engineering, 8*, e7-e16.

Said, M., Abu Hasan, H., Mohd Nor, M. T., & Mohammad, A. W. (2016). Removal of COD, TSS and colour from palm oil mill effluent (POME) using montmorillonite. *Desalination and Water Treatment, 57*(23), 10490-10497.

Sakthivel, T., Venugopal, G., Durairaj, A., Vasanthkumar, S., & Huang, X. (2019). Utilization of the internal electric field in semiconductor photocatalysis: A short review. *Journal of Industrial and Engineering Chemistry, 72*, 18-30. doi:https://doi.org/10.1016/j.jiec.2018.12.034

Santosa, S. J. (2008). Palm oil boom in Indonesia: from plantation to downstream products and biodiesel. *CLEAN–Soil, Air, Water, 36*(5- 6), 453-465.

Šarić, A., Musić, S., Nomura, K., & Popović, S. (1999). FT-IR and 57Fe Mössbauer spectroscopic investigation of oxide phases precipitated from Fe(NO3)3 solutions. *Journal of Molecular Structure, 480-481*, 633-636. doi:https://doi.org/10.1016/S0022-2860(98)00829-1

Schleifer, P. (2016). Private Governance Undermined: India and the Roundtable on Sustainable Palm Oil. *Global Environmental Politics, 16*(1), 38-58. doi:10.1162/GLEP_a_00335

Schleifer, P., & Sun, Y. (2018). Emerging markets and private governance: the political economy of sustainable palm oil in China and India. *Review of International Political Economy*, 1-25. doi:10.1080/09692290.2017.1418759

Schultz, D. M., & Yoon, T. P. (2014). Solar synthesis: prospects in visible light photocatalysis. *Science, 343*(6174), 1239176.

Serpone, N. (1997). Relative photonic efficiencies and quantum yields in heterogeneous photocatalysis. *Journal of Photochemistry and Photobiology A: Chemistry, 104*(1-3), 1-12.

Serpone, N., Lawless, D., Khairutdinov, R., & Pelizzetti, E. (1995). Subnanosecond Relaxation Dynamics in TiO2 Colloidal Sols (Particle Sizes Rp = 1.0-13.4 nm). Relevance to Heterogeneous Photocatalysis. *The Journal of Physical Chemistry, 99*(45), 16655-16661. doi:10.1021/j100045a027

Shah, A. P., Jain, S., Mokale, V. J., & Shimpi, N. G. (2019). High performance visible light photocatalysis of electrospun PAN/ZnO hybrid nanofibers. *Journal of Industrial and Engineering Chemistry, 77*, 154-163. doi:https://doi.org/10.1016/j.jiec.2019.04.030

Shaham-Waldmann, N., & Paz, Y. (2016). Away from TiO2: A critical minireview on the developing of new photocatalysts for degradation of contaminants in water. *Materials Science in Semiconductor Processing, 42*, 72-80. doi:10.1016/j.mssp.2015.06.068

Shak, K. P. Y., & Wu, T. Y. (2014). Coagulation–flocculation treatment of high-strength agro-industrial wastewater using natural Cassia obtusifolia seed gum: treatment efficiencies and flocs characterization. *Chemical Engineering Journal, 256*, 293-305.

Shavandi, M., Haddadian, Z., Ismail, M. H. S., Abdullah, N., & Abidin, Z. (2012). Removal of Fe (III), Mn (II) and Zn (II) from palm oil mill effluent (POME) by natural zeolite. *Journal of the Taiwan Institute of Chemical Engineers, 43*(5), 750-759.

Shimizu, K., & Mitani, T. (2009). *New horizons of applied scanning electron microscopy* (Vol. 45): Springer Science & Business Media.

Shirai, Y., Wakisaka, M., Yacob, S., Hassan, M. A., & Suzuki, S. i. (2003). Reduction of methane released from palm oil mill lagoon in Malaysia and its countermeasures. *Mitigation and Adaptation Strategies for Global Change, 8*(3), 237-252.

Sing, K. S., & Williams, R. T. (2004). Physisorption hysteresis loops and the characterization of nanoporous materials. *Adsorption Science & Technology, 22*(10), 773-782.

Smazna, D., Shree, S., Polonskyi, O., Lamaka, S., Baum, M., Zheludkevich, M., . . . Mishra, Y. K. (2019). Mutual interplay of ZnO micro- and nanowires and methylene blue during cyclic photocatalysis process. *Journal of Environmental Chemical Engineering, 7*(2), 103016. doi:https://doi.org/10.1016/j.jece.2019.103016

Smith, V. H., Tilman, G. D., & Nekola, J. C. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental pollution, 100*(1-3), 179-196.

Smyth, M., & Martin, J. (2000). x Ray crystallography. *Molecular Pathology, 53*(1), 8.

Soler-Cabezas, J. L., Torà-Grau, M., Vincent-Vela, M., Mendoza-Roca, J., & Martínez-Francisco, F. (2015). Ultrafiltration of municipal wastewater: Study on fouling models and fouling mechanisms. *Desalination and Water Treatment, 56*(13), 3427-3437.

Speltini, A., Maraschi, F., Sturini, M., Caratto, V., Ferretti, M., & Profumo, A. (2016). Sorbents Coupled to Solar Light TiO2-Based Photocatalysts for Olive Mill Wastewater Treatment. *International Journal of Photoenergy, 2016*.

Stasinakis, A. S. (2012). Review on the fate of emerging contaminants during sludge anaerobic digestion. *Bioresource technology, 121*, 432-440.

Su, R., Shen, Y., Li, L., Zhang, D., Yang, G., Gao, C., & Yang, Y. (2015). Silver-modified nanosized ferroelectrics as a novel photocatalyst. *Small, 11*(2), 202-207. doi:10.1002/smll.201401437

Sulaiman, N., Ghazali, M., Yunas, J., Rajabi, A., Majlis, B., & Razali, M. (2018). Synthesis and characterization of CaFe2O4 nanoparticles via co-precipitation and auto-combustion methods. *Ceramics International, 44*(1), 46-50.

Sundram, K., Sambanthamurthi, R., & Tan, Y.-A. (2003). Palm fruit chemistry and nutrition. *Asia Pacific journal of clinical nutrition, 12*(3).

Tabassum, S., Zhang, Y., & Zhang, Z. (2015). An integrated method for palm oil mill effluent (POME) treatment for achieving zero liquid discharge–a pilot study. *Journal of Cleaner Production, 95*, 148-155.

Tadza, M. Y. M., Ghani, N. A. F., & Sobani, H. H. M. (2016). Evaluation of sludge from coagulation of palm oil mill effluent with chitosan based coagulant. *Jurnal Teknologi, 78*(5-4).

Tay, J.-H. (1991). Complete reclamation of oil palm wastes. *Resources, conservation and recycling, 5*(4), 383-392.

Tchobanoglous, G., Burton, F. L., & Stensel, H. (1991). Wastewater engineering. *Management, 7*, 1-4.

Teh, C. Y., Budiman, P. M., Shak, K. P. Y., & Wu, T. Y. (2016). Recent advancement of coagulation–flocculation and its application in wastewater treatment. *Industrial & Engineering Chemistry Research, 55*(16), 4363-4389.

Tholkappiyan, R., & Vishista, K. (2014). Effect of niobium on the optical and magnetic properties of bismuth ferrite (BiFeO3). *Advanced Science, Engineering and Medicine, 6*(3), 311-317.

Tian, C., Zhang, Q., Wu, A., Jiang, M., Liang, Z., Jiang, B., & Fu, H. (2012). Cost-effective large-scale synthesis of ZnO photocatalyst with excellent performance for dye photodegradation. *Chemical Communications, 48*(23), 2858-2860. doi:10.1039/c2cc16434e

Tong, H., Ouyang, S., Bi, Y., Umezawa, N., Oshikiri, M., & Ye, J. (2012). Nano-photocatalytic materials: possibilities and challenges. *Advanced Materials, 24*(2), 229-251.

Tong, S., & Jaafar, A. B. (2006). POME Biogas capture, upgrading and utilization. *Palm Oil Engineering Bulletin, 78*(7).

Torkian, A., Eqbali, A., & Hashemian, S. (2003). The effect of organic loading rate on the performance of UASB reactor treating slaughterhouse effluent. *Resources, conservation and recycling, 40*(1), 1-11.

Vadivel, S., Maruthamani, D., Habibi-Yangjeh, A., Paul, B., Dhar, S. S., & Selvam, K. (2016). Facile synthesis of novel CaFe2O4/g-C3N4 nanocomposites for degradation of methylene blue under visible-light irradiation. *Journal of colloid and interface science, 480*, 126-136.

Villarroel-Rocha, J., Barrera, D., & Sapag, K. (2014). Introducing a self-consistent test and the corresponding modification in the Barrett, Joyner and Halenda method for pore-size determination. *Microporous and Mesoporous Materials, 200*, 68-78.

Viscarra Rossel, R. A., McGlynn, R. N., & McBratney, A. B. (2006). Determining the composition of mineral-organic mixes using UV–vis–NIR diffuse reflectance spectroscopy. *Geoderma, 137*(1), 70-82. doi:https://doi.org/10.1016/j.geoderma.2006.07.004

Wafti, N., Lau, H. L. N., Loh, S. K., Aziz, A. A., Ab Rahman, Z., & May, C. Y. (2017). Activated carbon from oil palm biomass as potential adsorbent for palm oil mill effluent treatment. *JOURNAL OF OIL PALM RESEARCH, 29*(2), 278-290.

Wang, F., Chen, D., Zhang, N., Wang, S., Qin, L., Sun, X., & Huang, Y. (2017). Oxygen vacancies induced by zirconium doping in bismuth ferrite nanoparticles for enhanced photocatalytic performance. *Journal of colloid and interface science, 508*, 237-247.

Wang, H., Zhang, L., Chen, Z., Hu, J., Li, S., Wang, Z., . . . Wang, X. (2014). Semiconductor heterojunction photocatalysts: design, construction, and photocatalytic performances. *Chemical Society Reviews, 43*(15), 5234-5244.

Wang, R.-M., Wang, Y., Ma, G.-P., He, Y.-F., & Zhao, Y.-Q. (2009). Efficiency of porous burnt-coke carrier on treatment of potato starch wastewater with an anaerobic–aerobic bioreactor. *Chemical Engineering Journal, 148*(1), 35-40. doi:https://doi.org/10.1016/j.cej.2008.07.028

Wang, Y., Shi, R., Lin, J., & Zhu, Y. (2011). Enhancement of photocurrent and photocatalytic activity of ZnO hybridized with graphite-like C 3N 4. *Energy and Environmental Science*, *4*(8), 2922-2929. doi:10.1039/c0ee00825g

Wang, Y. G., Lau, S. P., Lee, H. W., Yu, S. F., Tay, B. K., Zhang, X. H., . . . Hng, H. H. (2003). Comprehensive study of ZnO films prepared by filtered cathodic vacuum arc at room temperature. *Journal of Applied Physics, 94*(3), 1597-1604. doi:10.1063/1.1592007

Wang, Z., Chen, M., Huang, D., Zeng, G., Xu, P., Zhou, C., . . . Wang, W. (2019). Multiply structural optimized strategies for bismuth oxyhalide photocatalysis and their environmental application. *Chemical Engineering Journal, 374*, 1025-1045. doi:https://doi.org/10.1016/j.cej.2019.06.018

Wong, C., & Chu, W. (2003). The direct photolysis and photocatalytic degradation of alachlor at different TiO2 and UV sources. *Chemosphere*, *50*(8), 981-987.

Wu, S., Wang, C., Cui, Y., Wang, T., Huang, B., Zhang, X., . . . Brault, P. (2010). Synthesis and photocatalytic properties of BiOCl nanowire arrays. *Materials Letters*, *64*(2), 115-118. doi:10.1016/j.matlet.2009.10.010

Wu, T., Mohammad, A. W., Jahim, J. M., & Anuar, N. (2007). Palm oil mill effluent (POME) treatment and bioresources recovery using ultrafiltration membrane: effect of pressure on membrane fouling. *Biochemical Engineering Journal, 35*(3), 309-317.

Wu, T. Y., Mohammad, A. W., Jahim, J. M., & Anuar, N. (2010). Pollution control technologies for the treatment of palm oil mill effluent (POME) through end-of-pipe processes. *Journal of Environmental Management, 91*(7), 1467-1490.

Xia, J., Zhang, J., Yin, S., Li, H., Xu, H., Xu, L., & Zhang, Q. (2013). Advanced visible light photocatalytic properties of BiOCl micro/nanospheres synthesized via reactable ionic liquids. *Journal of Physics and Chemistry of Solids, 74*(2), 298-304.

Xiong, J., Cheng, G., Li, G., Qin, F., & Chen, R. (2011). Well-crystallized square-like 2D BiOCl nanoplates: mannitol-assisted hydrothermal synthesis and improved visible-light-driven photocatalytic performance. *RSC Advances*, *1*(8), 1542-1553.

Yacob, S., Hassan, M. A., Shirai, Y., Wakisaka, M., & Subash, S. (2005). Baseline study of methane emission from open digesting tanks of palm oil mill effluent treatment. *Chemosphere, 59*(11), 1575-1581.

Yacob, S., Hassan, M. A., Shirai, Y., Wakisaka, M., & Subash, S. (2006). Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment. *Science of the total environment, 366*(1), 187-196.

Ye, L., Zan, L., Tian, L., Peng, T., & Zhang, J. (2011). The {001} facets-dependent high photoactivity of BiOCl nanosheets. *Chemical Communications, 47*(24), 6951-6953.

Zahrim, A., Nasimah, A., & Hilal, N. (2014). Pollutants analysis during conventional palm oil mill effluent (POME) ponding system and decolourisation of anaerobically treated POME via calcium lactate-polyacrylamide. *Journal of Water Process Engineering, 4*, 159-165.

Zainal, N. H., Aziz, A. A., Ibrahim, M. F., IDRISǂ, J., Hassan, M. A., Bahrin, E. K., . . . ABD-AZIZ, S. (2018). CARBONISATION-ACTIVATION OF OIL PALM KERNEL SHELL TO PRODUCE ACTIVATED CARBON AND METHYLENE BLUE ADSORPTION KINETICS. *JOURNAL OF OIL PALM RESEARCH, 30*(3), 495-502.

Zainal, N. H., Jalani, N. F., Mamat, R., & Astimar, A. (2017). A review on the development of Palm Oil Mill Effluent (POME) final discharge polishing treatments. *JOURNAL OF OIL PALM RESEARCH, 29*(4), 528-540.

Zaleska, A. (2008). Doped-TiO2: a review. *Recent patents on engineering, 2*(3), 157-164.

Zangeneh, H., Zinatizadeh, A. A., Feyzi, M., Zinadini, S., & Bahnemann, D. W. (2018). Photomineralization of recalcitrant wastewaters by a novel magnetically recyclable boron doped-TiO2-SiO2 cobalt ferrite nanocomposite as a visible-driven heterogeneous photocatalyst. *Journal of Environmental Chemical Engineering, 6*(5), 6370-6381. doi:https://doi.org/10.1016/j.jece.2018.10.001

Zhang, K. L., Liu, C. M., Huang, F. Q., Zheng, C., & Wang, W. D. (2006). Study of the electronic structure and photocatalytic activity of the BiOCl photocatalyst. *Applied Catalysis B: Environmental, 68*(3-4), 125-129. doi:10.1016/j.apcatb.2006.08.002

Zhang, Q., Lima, D. Q., Lee, I., Zaera, F., Chi, M., & Yin, Y. (2011). A highly active titanium dioxide based visible- light photocatalyst with nonmetal doping and plasmonic metal decoration. *Angewandte Chemie International Edition, 50*(31), 7088-7092.

Zhang, X., Li, B., Wang, J., Yuan, Y., Zhang, Q., Gao, Z., . . . Chen, L. (2014). The stabilities and electronic structures of single-layer bismuth oxyhalides for photocatalytic water splitting. *Physical Chemistry Chemical Physics, 16*(47), 25854-25861. doi:10.1039/c4cp03166k

Zhang, Y., Li, Y., Lina, C., Xiuhua, L., Zhijian, M., & Zhang, Z. (2008). Startup and operation of anaerobic EGSB reactor treating palm oil mill effluent. *Journal of Environmental Sciences, 20*(6), 658-663.

Zhang, Y., Ye, H., Zheng, X., Zhang, Z., & Yan, L. (2011). High-rate mesophilic anaerobic digestion of palm oil mill effluent (POME) in expanded granular sludge bed (EGSB) reactor. *Advances in Biomedical Engineering*, 3-5.

Zhang, Z., & Wang, W. (2014). Solution combustion synthesis of CaFe2O4 nanocrystal as a magnetically separable photocatalyst. *Materials Letters, 133*, 212-215.

Zhao, Y., Lin, C., Bi, H., Liu, Y., & Yan, Q. (2017). Magnetically separable CuFe2O4/AgBr composite photocatalysts: Preparation, characterization, photocatalytic activity and photocatalytic mechanism under visible light. *Applied Surface Science, 392*, 701-707.

Zhu, J., Deng, Z., Chen, F., Zhang, J., Chen, H., Anpo, M., . . . Zhang, L. (2006). Hydrothermal doping method for preparation of Cr3+-TiO2 photocatalysts with concentration gradient distribution of Cr3+. *Applied Catalysis B: Environmental, 62*(3-4), 329-335.

Zinatizadeh, A. A., Ibrahim, S., Aghamohammadi, N., Mohamed, A. R., Zangeneh, H., & Mohammadi, P. (2017). Polyacrylamide-induced coagulation process removing suspended solids from palm oil mill effluent. *Separation Science and Technology, 52*(3), 520-527.