A COMBINED ADSORPTION AND OZONATION PROCESS FOR REMOVAL OF LINDANE IN AQUEOUS MEDIUM

NORMAIZATULAKMAR BINTI RAHMAT

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy in Environment

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

OCTOBER 2019

ACKNOWLEDGEMENT

Beautiful praises to Allah the Almighty and All-knowing for giving me His permission and blessings to complete this study successfully. I want to express my deepest gratitude to my supervisor, Dr. Salmiati, Dr. Tony Hadibarata and Prof Mohd Razman Salim for their supervision, advice and guidance and support throughout the research.

Special thanks dedicated to all staffs and technicians of Universiti Teknologi Malaysia's Environmental laboratory and IPASA for their help, assistance and providing the facilities for me to complete the project. Also not forgot, team members of group LRGS VOTE 4L810 for advice, guidance regarding laboratory work, critics and friendship. Also a special thanks to my lab partner, who have been together with me, all of the lecturers, staffs and to the rest who involved directly or indirectly. Thanks for all the love and grief that we shared.

I would also like to express my gratitude to my beloved parents, Mr. Rahmat Bin Latib, and Mrs. Norizan Binti Md Salleh and to all my siblings for their prayers, encouragement, and support. I hope this thesis will be useful for future use.

ABSTRACT

Gamma-hexachlorocyclohexane or lindane (γ-HCH) removal using a combination method of adsorption and ozonation was investigated. Lindane is one of the persistent organochlorine pollutants (POPs), used as a pesticide commonly in agricultural industry. The combination of both methods was studied based on adsorptive capability of banana fronds activated carbon which act as an adsorbent and powerful ozonation agent. The raw banana frond was impregnated with $ZnCI_2$ prior to the process of carbon activation. Gas Chromatography-Flame Ionization Detector (GC-FID) equipment was used to analyze the concentration of lindane solution before and after treatment. The formation of ozone in aqueous solution was studied by using Ultraviolet-Visible Spectrophotometry (UV-Vis). The study showed that the highest removal of lindane was achieved at 91% by using the adsorption method, 92% by using ozonation method and 99% by using a combination of both methods. The equilibrium data of adsorption was analyzed using two isotherm models Langmuir and Freundlich, and Langmuir isotherm (R^2 = 0.99) was found to fit the data better than Freundlich isotherm. The adsorption kinetics was studied, and the study indicated that the kinetic model followed pseudo-second-order (R^2 = 0.99). The functional groups of adsorbents were investigated using Fourier Transform Infrared Spectroscopy (FTIR), and it was found that a large number of carbonyl groups that represent hydrogen bond and hydroxyl groups had influenced the capability of adsorption by the banana fronds activated carbon towards lindane. In addition, the surface morphology of adsorbent was investigated using Field Emission Scanning Electron Microscope (FESEM). The study showed an increment of available pore sites after carbon activation of raw banana fronds soaked with $ZnCI_2$. Brunauer-Emmett-Teller (BET) supported by the FESEM results shows 4.86 m2/g and 4.77 m^2/g of available pore sites for banana fronds activated carbon with and without impregnation of $ZnCI_2$ activated carbon, respectively. The results proved that the combination method of adsorption and ozonation is a highly potential method for the removal of lindane in aqueous solution.

ABSTRAK

Penyingkiran gamma-heksaklorosikloheksane atau lindana (γ-HCH) menggunakan kaedah gabungan penjerapan dan pengozonan telah dikaji. Lindana adalah salah satu daripada bahan pencemar organoklorin kekal (POPs), yang biasa digunakan sebagai racun makhluk perosak dalam industri pertanian. Gabungan kedua-dua kaedah telah dikaji kerana ia menggunakan keupayaan penjerapan pelepah pisang karbon teraktif sebagai bahan penjerap dan agen pengozonan yang berkesan. Pelepah pisang perlu direndam dengan $ZnCI_2$ terlebih dahulu sebelum proses pengaktifan karbon. Peralatan pengesan kromatografi gas pengesan ion nyala (GC-FID) digunakan untuk menganalisis kepekatan lindana dalam larutan sebelum dan selepas dirawat. Pembentukan ozon dalam larutan akueus dikaji dengan menggunakan spektrofotometer ultra lembayung-nampak (UV-Vis). Kajian ini menunjukkan bahawa penyingkiran tertinggi adalah pada 91% dengan menggunakan kaedah penjerapan, 92% mengunakan kaedah pengozonan dan 99% menggunakan penggabungan kedua-dua kaedah. Data keseimbangan penjerapan dianalisis dengan menggunakan dua model isotem Langmuir dan Freundlich dan isotem Langmuir (R^2 = 0.99) lebih bersesuaian dengan data berbanding isotem Freundlich. Kinetik penjerapan telah dikaji dan menunjukkan model kinetik mengikuti pseudo-turutan-kedua (R^2 = 0.99). Kumpulan berfungsi bagi penjerap telah disiasat menggunakan Spektroskopi Inframerah Transformasi Fourier (FTIR) dan mendapati sebilangan besar kumpulan karbonil yang terdiri daripada hidrogen dan hidroksil telah mempengaruhi keupyaan penjerapan pelepah pisang karbon teraktif terhadap lindana. Morfologi permukaan bahan penjerap telah dianalisis menerusi Mikroskop Elektron Imbasan Pelepasan Medan (FESEM). Kajian ini menunjukkan peningkatan liang sedia ada selepas pengaktifan karbon daripada pelepah pisang yang direndam dengan $ZnCI_2$. Keputusan Brunauer-Emmett-Teller (BET) yang telah disokong oleh FESEM mendapati 4.86 m2/g dan 4.77 m^2/g liang yang ada bagi karbon aktif pelepah pisang dengan dan tanpa direndam $ZnCI_2$. Keputusan membuktikan bahawa kaedah gabungan antara penjerapan dan pengozonan adalah kaedah yang berpotensi tinggi untuk penyingkiran lindana dalam larutan akues.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	-	Activated Carbon
AOPs	-	Advanced Oxidation Processes
BET	-	Brunauer-Emmett-Teller
BFAC	-	Banana Fronds Activated Carbon
BFC	-	Biomimetic Fat Cell
BHC	-	Benzene Hexachloride
BOD	-	Biological Oxygen Demand
BPA	-	Bisphenol A
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
EDCs	-	Endocrine Disrupting Compounds
EPA	-	Environmental Protection Agency
FDA	-	Food and Drug Administration
FESEM	-	Field Emission Scanning Electron Microscopy
FTIR	-	Fourier Transform Infrared Spectroscopy
GAC	-	Granular Activated Carbon
GC-FID	-	Gas Chromatography-Flame Ionization Detector
HCH	-	Hexachlorocyclohexane
INQUINOSA	-	Industrias Quimicas del Noroeste Sociedad Anónima
IUPAC	-	International Union of Pure and Applied Chemistry
NOM	-	Natural Organic Matter
PAC	-	Powder Activated Carbon
POPs	-	Persistent Organochlorine Pesticides
PPCPs	-	Pharmaceuticals and Personal Care Products
SS	-	Suspended Solids
TOC	-	Total Organic Carbon
UNEP	-	United Nations Environment Programme
UV	-	Ultra Violet
UV-Vis	-	Ultraviolet-Visible Spectrophotometry
WHO	-	World Health Organization

LIST OF SYMBOLS

g	-	Gram
m	-	Moles
°C	-	Celsius
%	-	Percent
ng	-	Nanogram
L	-	Litre
mg	-	Milligram
α	-	Lpha
β	-	Beta
γ	-	Gamma
δ	-	Delta
ε	-	Epsilon
η	-	Eta
Ɵ	-	Theta
Pa	-	Pascal
K_{oc}	-	Soil sorption coefficient
mm	-	Millimeter
Hg	-	Mercury
kg	-	Kilogram
ppm	-	Parts per million
K_{OW}	-	Partition coefficient
cm^3	-	Centimeter cube
µ	-	Micro
O_3	-	Ozone
•OH	-	Hydroxyl radicals
min	-	Minute
mM	-	Millimolar
V	-	Volt

H_2O_2	-	Hydrogen Peroxide
OH^-	-	Hydroxide ions
nm	-	Nanometer
MW	-	Molar weight
mL	-	Milliliter
cm	-	Centimeter
d	-	Diameter
KOH	-	Potassium hydroxide
K_2CO_3	-	Potassium carbonate
$ZnCI_2$	-	Zinc chloride
NaOH	-	Sodium hydroxide
KI	-	Potassium iodide
HCI	-	Hydrochloric acid
H	-	Hour
q_e	-	Equilibrium adsorption capacity
Q_m	-	Maximum adsorption capacity
C_o	-	Initial concentration
C_e	-	Equilibrium concentration
KBr	-	Potassium bromide
K	-	Kelvin
N_2	-	Nitrogen

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Study

Pesticides are chemicals commonly used in the agriculture industry as plant protection to control the quality of products by destroying pests. The pesticide comprised of insecticide, herbicide, molluscicide, nematicide, avicide, piscicide, rodenticide, bactericide, animal and insect repellent, fungicide, antimicrobial, sanitizer, and disinfectant. Pesticides are not only used in the agriculture sector but also as non-agricultural purposes since it works to attract, seduce, and destroy any pests.

Besides that, some pesticides used for medical applications that act as prevention of vector-borne diseases such as malaria and dengue. The vector-borne disease, which represents one of the major global health issues, also become one of the reasons for the high demand of pesticides. Not just that, the ever-increasing demand for food has cause the increase in agriculture activity which led to highly pesticide application to feed a growing world population (Pavlíková *et al.*, 2012).

Even though it has many benefits since it can destroy any pests, but it also produce side effects in terms of health issues. Over the last decades, the public and government has been concerning the potential hazards of the uncontrolled use of pesticides. In Malaysia there are several legislations in regards to these issues such as Pesticides Act 1974, Poison Act 1952, the Environmental Quality Act 1974, Fumigation of Hydrogen Cyanide Act 1953, Occupational Safety and Health Act 1994 and many regulations and guidelines (Ali and Shaari, 2015).

Thus, a large number of researchers have studied the effects of pesticides that pose serious human health and ecosystem issues. Some of these pesticides are grouped as persistent organochlorine pollutants (POPs) and are considered as most toxic pesticides due to their persistence behavior in the environment and toxicity towards the human. According to the United Nations Environment Program (UNEP), POPs defined as a chemical that persists or non-degradable in the environment even through chemical or biological degradation. Therefore, the pesticide is bio-accumulated through the food web, long-term toxicity in soils, water, sediments, and biota, and can cause health effects towards human and the environment (Laver, 2015).

Since POPs are non-polar pesticides, their molecules can accumulate in fatty tissues and promote their biomagnification in the food chain (Jacob, 2013). As a result, high concentration of these molecules often found in tissues, adipose tissues or fat, milk and serum of human beings because POPS are top in the food web (Lee *et al*., 2017). Due to their high persistence in the environment even though through chemical and biological degradation, the Stockholm Convention has banned the use of pesticides under the POPs group since 2009.

Gamma-hexachlorocyclohexane (γ-HCH), which is known as lindane, a member of the POPs group is commonly used as insect pests in the agriculture industry due to its's insecticide behavior. Besides that, it was also being used for medicinal and public health applications. In medical applications basically, lindane is formulated as lotion or shampoo to treat lice and scabies (Goldust *et al*., 2013).

Lindane is a colorless to brown crystalline which exist in the form of powder or solid with a molecular weight of 290.83 g/mol and a melting point of 112°C (Laver, 2015). The solubility of lindane practically can be performed with a presence of ethanol, benzene, chloroform, acetone, or ether since it is insoluble with water (Report on Carcinogens, 2011). Based on the previous study has been reported that lindane had been detectable in biological samples such as urine, serum, semen, adipose tissue, milk, and brain, in fact, it also can be found in environmental samples such as surface water, wastewater, groundwater, soil, fish, and vegetables (Wang and Liang, 2018; Lee *et al.*, 2017).

Due to the concern of decreased in water quality, a few conventional methods have been developed to apply for pesticides removal from water. Therefore, the treatment process of pesticides has becomes a real challenge due to variable concentration and volume to meet the quality standards for a direct discharge of pesticides into the surface water. Several methods introduced to overcome the critical issue of these pesticides including adsorption (Tor *et al.*, 2013), the simultaneous presence of coagulants and adsorption (Shabeer *et al*., 2014), treatments with nanoparticles (Román *et al.*, 2016), ozonation (Begum and Gautam, 2012), photo-Fenton process (Nitoi *et al*., 2013) and biological degradation (Pannu and Kumar, 2017; Satish *et al.*, 2017).

Among pesticides treatment technologies that have implemented before, adsorption and ozonation is a commonly used method for the pesticide treatment process. In recent years, treatment process of contaminated water and wastewater through a combination of adsorption by activated carbon (AC) and ozonation has emerged as one of the best options by researchers.

Adsorption is a process by which molecules, atoms, or ions with particular characteristics of size and polarity from the liquid phase are attracted and held to the adsorbent surfaces (El-Essawy *et al.*, 2017). The activated carbon has been proposed to be the most efficient adsorbent due to its high surface area and adsorptive capability to remove contaminants from solution rapidly and effectively (Lazim, 2016). Besides, in the combination of adsorption and ozonation methods, the AC will accelerate the decomposition rate of the ozone (O_3) to form hydroxide ions (OH^-) in the solution (Abdedayem *et al.,* 2017). However, the overlying cost of commercial AC, cause the past researchers looking for another alternative that could save the cost of AC preparation (Wirasnita, 2015).

Generally, activated carbon from agricultural waste is an inexpensive material suitable to replace commercial AC. Moreover, the effectiveness of agricultural waste AC to remove pesticides from contaminated water or wastewater has proved through the study of chlorothalonil removal by casuarina charcoal (Gar Alalm and Nasr, 2018), metribuzin and furadan removal by bamboo (Santana *et al.*, 2017), 2,4-dichlorophenoxyacetic acid removal by langsat empty fruit bunch (Njoku *et al.*, 2015), diuron removal by wood composites (Cansado *et al.*, 2017), and lindane removal by date stones (El-Kady *et al*., 2013).

On the other hand, the ozonation method is considered as the most efficient methods due to their availability of most powerful oxidant agents (Sousa *et al*., 2018). It is one of the promising techniques for water and wastewater disinfection and capable of degrading many target compounds (Umar *et al*., 2013). Recent years, some researchers reported that ozonation method are also be used to remove various type of pesticides such as beta-hexachlorocyclohexane (Cruz-González *et al.*, 2018), atrazine (Zhou *et al.*, 2016), permethrin (Chen *et al.*, 2013), endosulfan (Landeros *et al.*, 2017), chlorpyrifos ethyl (Kusvuran *et al.*, 2012) among many others. Different published works have reported that oxidation of wastewater by O_3 to remove lindane which has resulted in 82% removal (Begum and Gautam, 2012), 58.8% removal (Derco *et al*., 2013), and 55% removal (Ormad *et al*., 2008).

1.2 Problem Statement

Excessive use of lindane has been one of the major source of environmental pollution because it can affect human health, animal, and ecosystem due to it's' toxicity. The toxicity of lindane may interrupt the ecosystem of the environment, especially to the surface water. The presence of lindane in the human body system as a result of lindane use and exposure, which caused health issue has raised concern to control the usage of lindane. It may affect the liver, kidneys, nervous system, and can be a carcinogen. The Stockholm Convention on Persistent Organic Pollutants has proclaimed the use of lindane in the agriculture sector was banned.

There are a lot of conventional methods that have introduced to treat pesticides. However, the results obtained from the past study showed that the lindane not totally can be removed even after the treatment due to their persistence behavior and design with strong bonding. Thus, this study investigated the potential of a combination of two conventional methods which are adsorption by using AC and ozonation as to maximize the possibility to degrade lindane from aqueous solution.

The previous study reported there are beneficial effects of removing pollutants or organic matter from water through a combination of adsorption by using AC and ozonation. The presence of AC in O_3 reaction acts as a promoting agent of hydroxide radicals in the ozonated sample and can increase the reaction rate of removal (Guiza *et al.*, 2004). Besides, AC is often used as catalyst support because it can satisfy most of the desirable properties required for suitable support.

The others problem in the study of lindane removal is also related to the cost of treatment preparation. Due to the high cost of commercial AC preparation, there is an alternative way to provide AC inexpensively by identified the potential agricultural waste as an adsorbent to promote lindane removal. In this study, banana fronds from the banana tree, which belongs to the family *Musaceae* were chosen as a potential agricultural waste to replace commercial AC.

The banana fronds have been extensively used as an agriculture waste AC due to its abundantly available since it provides one of the highest nutritional fruit crops cultivated around the world and considered as economical adsorbents while against cationic, anionic, and neutral pollutants (Ahmad and Danish, 2018). Furthermore, raw banana fronds can be chemically modified to prepare a better AC and may present as a good adsorbent against various pollutants compared to commercial AC.

The banana frond is potential to replace the commercial AC because it is readily available, and in term of the cost, it is more affordable compared to commercial AC. Besides, the composition of banana fronds, which consists of lignocellulosic material, can provide a better porous of activated carbon (Suhas *et al.*, 2016). Not just that, the lignocellulosic waste had a high carbon content which performs a better behavior of activated carbon (Santos-Clotas *et al.*, 2019).

1.3 Research Objectives

The present study aims to investigate the potential of the combination of adsorption by using AC produce from banana fronds and ozonation for lindane removal in aqueous solution. The specific objectives of the study are as follows:

i. To study the effect of impregnation methods using different chemical of producing banana fronds activated carbon (BFAC).
ii. To analyze the effects of physico-chemical parameters for the lindane removal by using activated carbon and ozonation treatment.
iii. To evaluate the adsorption kinetics and isotherms of lindane on activated carbon.
iv. To determine the maximum percentage of lindane removal by combining activated carbon and ozonation treatment.

1.4 Scopes of Study

This study focuses on the treatment of lindane in aqueous solution by using a method of combination of adsorption and ozonation. The banana fronds were used as an agricultural waste AC to investigate their potential as an adsorbent for lindane removal. In preparation of BFAC, a few chemical reagents which are zinc chloride ($ZnCI_2$), sodium hydroxide (NaOH), potassium carbonate (K_2CO_3) and potassium hydroxide (KOH) used to impregnate with raw banana fronds before carbon activation as to increase their adsorption capability.

Batch studies of adsorption treatment were performed to study the effects of mass adsorbent, initial concentration of lindane, and contact time towards lindane removal. The characteristics of the adsorbent before and after treatment investigated through FTIR, FESEM, and BET. Adsorption mechanisms were investigated through adsorption isotherms and adsorption kinetics, which are Langmuir and Freundlich isotherm model and pseudo-first-order, pseudo-second-order, and intraparticle diffusion model respectively.

Batch studies of ozonation treatment were performed to study the effects of contact time, pH level, initial concentration of lindane, and ozone dosage. The formation of O_3 in aqueous solution studied by using Ultraviolet-Visible Spectrophotometry (UV-Vis). The study of the combination of both methods was performed based on the optimum results obtained from the operating parameters studies in individual experiments. In individual and combination studies, the Gas Chromatography-Flame Ionization Detector (GC-FID) equipment was performed to analyze lindane pollutants in solution.

1.5 Limitation of Study

In this study, there are a few limitation needed to be considered during the experiments. Firstly, during the process of carbon activation of banana fronds, the temperature of the pyrolysis process needs to be set at 400°C as the fiber composition of banana fronds will affect the quality of the activated carbon. If the temperature is set too high, the banana fronds would transform into ash. While, if the temperature were too low, the banana fronds would not be completely transform into activated carbon.

Besides that, the pollutants solution are being prepared in milligram per liter volume as the equipment of GC-FID cannot detect the low volume of pollutants in the solution. The studied sample solution are prepared in duplicate samples due to the fast reactions of O_3 that might interrupt the study of contact time due to sample withdrawn process.

1.6 Significance of Research

The significance of this study is to provide a potential method through a combination of adsorption by BFAC and ozonation for lindane removal in aqueous solution. Even though several studies have reported the removal of lindane through adsorption and ozonation method, but there is still no result which completely removes lindane from aqueous solution. In the current knowledge, there is no report investigating the removal of lindane through the combination of both adsorption and ozonation methods, as a promising way to increase the efficiency of lindane removal.

Besides, the utilization of BFAC to replace commercial AC is environmentally friendly, inexpensive, sustainable resources, and easy to get. Furthermore, agricultural waste AC is expected to be more effective adsorbent to remove lindane particles due to their special microporous structure, and high surface area and volume. It also can act as promoting agents to accelerate the transformation of O_3 to form hydroxyl free radicals. By optimizing of both methods, it might solve the crisis of water contamination by lindane and resulting in reduces of exposure towards human and wildlife.

REFERENCES

Abdedayem, A., Guiza, M., Toledo, F.J.R., & Ouederni, A. (2017). Nitrobenzene degradation in aqueous solution using ozone/cobalt supported activated carbon coupling process: A kinetic approach. *Separation and Purification Technology,* 184, 308-318.

Abdurrahman, F., Akter, M., & Abedin, M.Z. (2013). Dyes removal from textile wastewater using orange peels. *Journal of Scientific & Technology*, 2(9), 47-50.

Achak, M., Hafidi, A., Ouazzani, N., Sayadi, S., & Mandi, L. (2009). Low cost biosorbent "banana peel" for the removal of phenolic compounds from olive mill wastewater: kinetic and equilibrium studies. *Journal of Hazardous Materials*, 166(1), 117-125.

Adib, M.R.M., Suraya, W.M.S.W., Rafidah, H., Amirza, A.R.M., Attahirah, M.H.M.N., Hani, M.S.N.Q., & Adnan, M.S. (2016). Effecr of phosphoric acid concentration on the characteristics of sugarcane bagasse activated carbon. *IOP Conference Series: Materials Science and Engineering*, 136, 012061.

Ahmad, N.A., Yuzir, M.A., Yong, E.L., Abdullah, N., & Salim, M.R. (2015). Removal of bisphenol A (BPA) in surface water by ozone oxidation process. *Applied Mechanics and Materials*, 735, 210-214.

Ahmad, T., & Danish, M. (2018). Prospects of banana waste utilization in wastewater treatment: A review. *Journal of Environmental Management,* 206, 330-348.

Ahmadpour, A., & Do, D.D. (1997). The preparation of activated carbon from macadamia nutshell by chemical activation. *Carbon*, 35, 1723-1732.

Akhtar, M., Hasany S.M., Bhanger, M.I., & Iqbal, S. (2007). Low cost sorbents for the removal of methyl parathion pesticide from aqueous solutions. *Chemosphere,* 66, 1829-1838.

Akron. (2009). The chemical database. The Department of Chemistry, University of Akron.

Alalm, M.G., & Nasr, M. (2018). Artificial intelligence, regression model, and cost estimation for removal of chlorothalonil pesticide by activated carbon prepared from casuarina charcoal. *Sustainable Environment Research*, 28(3), 101-110.

Alalm, M.G., Tawfik, A., & Ookawara, S. (2015). Combined solar advanced oxidation and PAC adsorption for removal of pesticides from industrial wastewater. *Journal Material Environmental Science*, 6, 800-809.

Ali, A., & Shaari, N. (2015). Mismanagement of chemical agriculture in Malaysia from legal perspective. *Procedia Economics and Finance*, 31, 640-650.

Al-Othman, Z.A., Ali, R., & Naushad, Mu. (2012). Hexavalent chromium removal from aqueous medium by activated carbon prepared from peanut shell: Adsorption kinetics, equilibrium and thermodynamic studies. *Chemical Engineering Journal*, 184, 238–247.

Anisuzzaman, S.M., Joseph, C.G., Taufiq-Yap, Y.H., Krishnaiah, D., & Tay, V.V. (2015). Modification of commercial activated carbon for the removal of 2,4-dichlorophenol from simulated wastewater. *Journal of King Saud University-Science,* 27, 318-330.

Annadurai, G., Juang, R., & Lee, D. (2003). Adsorption of heavy metals from water using banana and orange peels. *Water Science and Technology*, 47(1), 185-190.

ATSDR – Priority List of Hazardous Substances, (2013). A*gency for Toxic Substances and Disease Registry*.

Ay, C.O., Özcan, A.S., Erdogan, Y., & Özcan, A. (2012). Characterization of Punica granatum L. peels and quantitatively determination of its biosorption behavior towards lead (II) ions and Acid Blue 40. *Colloids and Surfaces B: Biointerfaces*, 100, 197-204.

Aziz, N.A.A., Palantandy, P., & Aziz, H.A. (2017). Photocatalytic degradation of lindane and DDT using TiO_2/solar light by response surface methodology. *Science International (Lahore)*, 29(1), 63-67.

Bagheri, N., & Abedi, J. (2011). Adsorption of methane on corn cobs based activated carbon. *Chemical Engineering Research and Design*, 89, 2038-2043.

Bajaj, S., Sagar, S., Khare, S., & Singh, D.K. (2017). Biodegradation of g-hexachlorocyclohexane (lindane) by halophilic bacterium Chromohalobacter sp. LD2 isolated from HCH dumpsite. *International Biodeterioration and Biodegradation*, 122, 23-28.

Bajaj, S., & Singh, D. (2015). Biodegradation of persistent organic pollutants in soil, water and pristine sites by cold-adapted microorganisms: mini review. *International Biodeterioration and Biodegradation*, 100, 98-105.

Bedin, K.C., Martins, A.C., Cazetta, A.L., Pezoti, O., & Almeida, V.C. (2016). KOH-activated carbon prepared from sucrose spherical carbon: adsorption equilibrium, kinetic and thermodynamic studies for methylene blue removal. *Chemical Engineering Journal*, 286, 476–484.

Begum, A., Agnihotri, P., Mahindrakar, A.B., & Gautam, S.K. (2017). Degradation of endosulfan and lindane using Fenton's reagent. *Applied Water Sciences*, 7(1), 207-215.

Begum, A., & Gautam, S.K. (2012). Endosulfan and lindane degradation using ozone. *Environmental Technology*, 33(7-9), 943-949.

Belfiore, N.M., & Anderson, S.L. (2001). Effects of contaminants on genetic patterns in aquatic organisms: A review. *Mutation Research/Reviews in Mutation Research*, 489, 97–122.

Beltrán, F.J., Rivas, J., & Acedo, B. (2008). Atrazine removal by ozonation processes in surface waters. *Journal of Environment Science and Health, Part B*, 34(3), 449-468.

Benimeli, M.S., Fuentes, C.M., Abate, M.J., & Amoroso. (2008). Bioremediation of lindane-contaminated soil by Streptomyces sp. M7 and its effects on Zea maysgrowth. *International Biodeterioration and Biodegradation*, 61, 233–239.

Bhatnagar, A., Sillanpää, M., & Witek-Krowiak, A. (2015). Agricultural waste peels as versatile biomass for water purification: A review. *Chemical Engineering Journal*, 270, 244–271.

Bhattacharjee, D., & Das, S. (2013). Toxicity of organochlorine pesticide, Lindane to fish: A review. *Journal of Chemical and Pharmaceutical Research,* 5(4): 90-96.

Bidlan, R., Afsar, M., & Manonmani, H.K. (2004). Bioremediation of HCH-contaminated soil: Elimination of inhibitory effects of the insecticide on radish and green gram seed germination. *Chemosphere*, 56, 803–811.

Bouchelta, C., Medjram, M.S., Bertrand, O., & Bellat, J.P. (2008). Preparation and Characterization of Activated Carbon from Date Stones by Physical Activation with Steam. *Journal of Analytical and Applied Pyrolysis*, 82; 70-77.

Buah-Kwofie, A., Humphries, M.S., Combrink, X., & Myburgh, J.G. (2018). Accumulation of organochlorine pesticides in fat tissue of wild Nile crocodiles (Crocodylus niloticus) from iSimangaliso Wetland Park, South Africa. *Chemosphere*, 195, 463-471.

Budinova, T., Ekinci, E., Yardim, F., Grimm, A., Björnbom, E., Minkova, V., & Goranova, M. (2006). Characterization and application of activated carbon produced by H_3PO_4 and water vapor activation. *Fuel Processing Technology*, 87, 899–905.

Camacho-Perez, B., Ríos-Leal, E., Rinderknecht-Seijas, N., & Poggi-Varaldo, H.M. (2012). Enzymes involved in the biodegradation of hexachlorocyclohexane: A mini review. *Journal Environmental Management*, 95, S306-S318.

Cansado, I.P.P., Mourão, P.A.M., Gomes, J.A.F.L., & Almodôvar, V. (2017). Adsorption of MCPA, 2,4-D and diuron onto activated carbons from wood composites. *Ciência & Tecnologia dos Materiais*, 29, 224-228.

Cecchine, G., Golomb, B.A., Hilborne, L.H., Spektor, D.M., & Anthony, C.R. (2000). A review of the scientific literature as it pertains to gulf war illnesses, volume 8. *National Defense Research Institute, RAND*.

Cecen, F., & Aktas, O. (2015). Activated carbon for water and wastewater treatment: Integration of adsorption and biological treatment. *Germany: John Wiley & Sons.*

Ceci, A., Pierro, L., Riccardi, C., Pinzari, F, Maggi, O., Persiani, A.M., Gadd, G.M., & Papini, M.P. (2015). Biotransformation of β-hexachlorocyclohexane by the saprotrophic soil fungus Penicillium griseofulvum. *Chemosphere*, 137, 101-107.

Chang, K.L., Hsieh, J.F., Ou, B.M., Chang, M.H., Hseih, W.Y., Lin, J.H., & Chen, S.T. (2012). Adsorption studies on the removal of an endocrine disrupting compound (Bisphenol A) Using Activated Carbon from Rice Straw Agricultural Waste. *Separation Science and Technology,* 47(10), 1514-1521.

Chen, J.Y., Lin, Y.J., & Kuo, W.C. (2013). Pesticide residue removal from vegetables by ozonation. *Journal of Food Engineering*, 114, 404-411.

Chen, X., Lam, K.F., Mak, S.F., Ching, W.K., Ng, T.N., & Yeung, K.L. (2012). Assessment of sericin biosorbent for selective dye removal. *Chinese Journal of Chemical Engineering*, 20, 426-432.

Concha-Grana, E., Turnes-Carou, M.I., Muniategui-Lorenzo, S., Lopez-Mahia, P., Prada-Rodriguez, D., & Fernández-Fernández, E. (2006). Evaluation of HCH isomers and metabolites in soils, leachates, river water and sediments of a highly contaminated area. *Chemosphere,* 64, 588-595.

Cruz-González, G., Julcour, C., Chaumat, H., Bourdon, V., Ramon-Portugal, F., Gaspard, S., & Jáuregui-Haza, U.J. (2018). Degradation of chlordecone and beta-hexachlorocyclohexane by photolysis, (photo-) fenton oxidation and ozonation. *Journal of Environmental Science and Health*, 53(2), 121-125.

Dai, X.D., Liu, X.M., Zhao, G., Qian, L., Qiao, K., & Yan, Z.F. (2008). Treatment of activated carbon for methane storage. *Asia-Pacific Journal of Chemical Engineering*, 3, 292–297.

Danish, M., and Ahmad, T. (2018). A review on utilization of wood biomass as a sustainable precursor for activated carbon production and application. *Renewable and Sustainable Energy Reviews*, 87: 1-21.

Dardouri, S., & Sghaier, J. (2017). A comparative study of adsorption and regeneration with different agricultural wastes as adsorbents for the removal of methylene blue from aqueous solution. *Chinese Journal of Chemical Engineering*, 25, 1282-1287.

Davidson, J., Good, C., Welsh, C., & Summerfelt, S. (2011). The effects of ozone and water exchange rates on water quality and rainbow trout Oncorhynchus mykiss performance in replicated water recirculating systems. *Aquacultural Engineering*, 44(3), 80-96.

De Oliveira, T.F., Chedeville, O., Fauduet, H., & Cagnon, B. (2011). Use of ozone/activated carbon coupling to remove diethyl phthalate from water: Influence of activated carbon textural and chemical properties. *Desalination*, 276, 359–365.

Demiral, H., Demiral, I., Tümsek, F., & Karabacakoğlu, B. (2008). Adsorption of chromium (VI) from aqueous solution by activated carbon derived from olive bagasse and applicability of different adsorption models. *Chemical Engineering Journal*, 144, 188-196.

Derco, J., Dudáš, J., Valičková, M., Šimovičová, K., & Kecskés, J. (2015). Removal of micropollutants by ozone-based processes. Chemical Engineering and Processing: *Process Intensification*, 94, 78-84.

Derco, J., Valičková, M., Šilhárová, K., Dudáš, J., & Luptáková, A. (2013). Removal of selected chlorinated micropollutants by ozonation. *Chemical Papers*, 67(12), 1585-1593.

Doğan, M., Abak, H., and Alkan, M. (2008). Biosorption of methylene blue from aqueous solutions by hazelnut shells: equilibrium, parameters and isotherms. *Water, Air, and Soil Pollution*, 192, 141-153.

Dominguez, C.M., Oturan, N., Romero, A., Santos, A., & Oturan, M.A. (2018a). Lindane degradation by electrooxidation process: Effect of electrode materials on oxidation and mineralization kinetics. *Water Research*, 135, 220-230.

Dominguez, C.M., Oturan, N., Romero, A., Santos, A., & Oturan, M.A. (2018b). Optimization of electro-Fenton process for effective degradation of organochlorine pesticide lindane. *Catalysis Today*, 313, 196-202.

Dominguez, C.M., Oturan, N., Romero, A., Santos, A., & Oturan, M.A. (2018c). Removal of lindane wastes by advanced electrochemical oxidation. *Chemosphere*, 202, 400-409.

Durie, A.J., Slawin, A.M.Z., Lebl, T., & O'Hogan, D. (2012). The synthesis of η-1,2,3,4,5,6-hexafluorocyclohexane (benzene hexafluoride) from benzene. *Angewandte Chemie*, 124, 10233-10235.

El-Essawy, N., Ali, S.M., Farag, H.A., Konsowa, A.H., Elnouby, M., & Hamad, H.A. (2017). Green synthesis of graphene from recycled PET bottle wastes for use in the adsorption of dyes in aqueous solution. *Ecotoxicology and Environmental Safety*, 145, 57-68.

El-Kady, A.A., Carleer, R., Yperman, J., & Farah, J.Y. (2013). Optimum conditions for adsorption of lindane by activated carbon derived from date stones. *World Applied Sciences Journal*, 27(2), 269-279.

Enjarlis, Bismo, S., Slamet, & Soemantojo, R.W. (2007). Kinetics degradation of carbofuran by ozonation in the presence of activated carbon. *14th Regional Symposium on Chemical Engineering.*

Enriquez-Victorero, C., Hernández-Valdés, D., Montero-Alejo, A.L., Durimel, A., Gaspard, S., & Jáuregui-Haza, U. (2014). Theoretical study of γ-hexachlorocyclohexane and β-hexachlorocyclohexane isomers interaction with surface groups of activated carbon model. *Journal of Molecular Graphics and Modelling*, 51, 137-148.

Ergene, A., Ada, K., Tan, S., & Katircioğlu, H. (2009). Removal of Remazol Brilliant Blue R dye from aqueous solutions by adsorption onto immobilized Scenedesmus quadricauda: Equilibrium and kinetic modeling studies. *Desalination*, 249; 1308-1314.

Evans, A.E.V., Hanjra, M.A., Jiang, Y., Qadir, M., & Dreschel, P. (2012). Water quality: Assessment of the current situation in Asia. *International Journal of Water Resources Development*, 28, 195-216.

Fernández, J., Arjol, M.A., and Cacho, C. (2013). POP-contaminated sites from HCH production in Sabiñánigo, Spain. *Environmental Science and Pollution Research International*, 20(4), 1937-1950.

Foo, K.Y., & Hameed, B.H. (2010). Detoxification of pesticide waste via activated carbon adsorption process. *Journal of Hazardous Materials*, 175, 1-11.

Fuentes, M.S., Benimeli, C.S., Cuozzo, S.A., & Amoroso, M.J. (2010). Isolation of pesticide degrading actinomycetes from a contaminated site: bacterial growth, removal and dichlorination of organochlorine pesticides. *International Biodeterioration and Biodegradation*, 64, 434-441.

Geçgel, Ű., Őzcan, G., & Gürpinar, G.Ç. (2013). Removal of methylene blue from aqueous solution by activated carbon prepared from pea shells (pisum sativum). *Journal of Chemistry,* DOI:10.1155/2013/614083

Gercel, O., & Gercel, H.F. (2007). Adsorption of lead (II) ions from aqueous solutions by activated carbon prepared from biomass plant material of Euphorbia rigida. *Chemical Engineering Journal*, 132, 289-297.

Ghaedi, M., Golestani Nasab, A., Khodadoust, S., Rajabi, M., & Azizian, S. (2014). Application of activated carbon as adsorbents for efficient removal of methylene blue: Kinetics and equilibrium study. *Journal of Industrial and Engineering Chemistry*, 20, 2317–2324.

Githinji, I.N. (2015). Screening and isolation of γ-hexachlorocyclohexane degrading bacteria from contaminated soil in Kenya. *Master Thesis, University of Nairobi.*

Gogate, P.R., & Pandit, A.B. (2004). A review of imperative technologies for waste water treatment I: Oxidation technologies at ambient conditions. *Advances Environmental Research*, 8, 501-551.

Goldust, M., Rezaee, E., Raghifar, R., & Naghavi-Behzad, M. (2013). Ivermectin vs lindane in the treatment of scabies. *Annals of Parasitology,* 59(1), 37-41.

Gonçalves, G.d.C., Pereira, N.C., & Veit, M.T. (2016). Production of bio-oil and activated carbon from sugarcane bagasse and molasses. *Biomass and Bioenergy*, 85, 178-186.

Gong, R., Liang, J., Chen, J., & Huang, F. (2009). Removal of bisphenol A from aqueous solution by hydrophobic sorption of hemimicelles. *International Journal of Environmental Science and Technology*, 6(4), 539-544.

González, R., Garcia-Balboa, C., Rouco, M., Lopez-Rodas, V., & Costas, E. (2012). Adaptation of microalgae to lindane: A new approach for bioremediation. *Aquatic Toxicology*, 109,25-32.

Grassi, M., Kaykioglu, G., Belgiorno, V., & Lofrano, G. (2012). Removal of emerging contaminants from water and wastewater by adsorption process. *Emerging Compounds Removal from Wastewater*, 15-37.

Ge, S., & Gorelick, S.M. (2015). Hydrology, floods, and droughts | Groundwater and surface water. *Encyclopedia Atmosphere Sciences (Second Edition),* 209-216.

Geueke, B., Garg, N., Ghosh, S., Fleischmann, T., Holliger, C., Lal, R., & Kohler H.P. (2013). Metabolomics of hexachlorocyclohexane (HCH) transformation: Ratio of LinA to LinB determines metabolic fate of HCH isomers. *Environmental Microbiology*, 15(4), 1040-1049.

Guillen-Jimeneza, F., Cristiani-Urbinab, E., Cancino-Dı´azc, J.C., Flores-Morenod, J.L., & Barraga´n-Huertaa, B.E. (2012). Lindane biodegradation by the Fusarium verticillioides AT-100 strain, isolated from Agave tequilana leaves: Kinetic study and identification of metabolites. *International Biodeterioration and Biodegradation*, 74, 36–47.

Guiza, M., Ouederni, & Ratel, A. (2010). Decomposition of dissolved ozone in the presence of activated carbon: An experimental study. *Ozone: Science & Engineering*. 26(3), 299-307.

Guiza, M., Ouederni, A., & Ratel, A. (2004). Decomposition of dissolved ozone in the presence of activated carbon. *An Experiment Study: Science & Engineering,* 26 (3), 299-307.

Gupta, V.K., Jain, C.K., Ali, I., Chandra, S., & Agarwal, S. (2002). Removal of lindane and malathion from wastewater using baggase fly ash-a sugar industry waste. *Water Resources*, 36(10), 2483-2490.

Gustavson, K., Hilbert, G., & Jorgensen, N.S. (1990). Occurrence, spreading and effects of pesticides in environment, studies on phenoxy acids and hexachlorocyclohexane. *Copenhagen, Ministry of Environment, National Agency of Environmental Protection and National Environmental Research Institute*.

Hameed, B.H., Krishni, R.R., & Sata, S.A. (2009). A novel agricultural waste adsorbent for the removal of cationic dye from aqueous solutions. *Journal of Hazardous Materials*, 162 (1), 305-311.

Hameed, B.H., Mahmoud, D.K., & Ahmad, A.L. (2008). Sorption equilibrium and kinetics of basic dye from aqueous solution using banana stalk waste. *Journal of Hazardous Materials*, 158(2–3), 499-506.

Hashemian, S., Salari, K., & Yazdi, Z.A. (2014). Preparation of activated carbon from agricultural wastes (almond shell and orange peel) for adsorption of 2-pic from aqueous solution. *Journal of Industrial and Engineering Chemistry*, 20, 1892-1900.

Heusinkveld, H., Thomas, G., Lamot, I., Van den Berg, M., Kroese, A., & Westerink, R.H.S. (2010). Dual actions of lindane (gamma-hexachlorocyclohexane) on calcium homeostasis and exocytosis in rat PC12 cells. *Toxicology and Applied Pharmacology*. 248, 12–19.

Hill, M.K. (2010). Water Pollution. Understanding Environmental Pollution. 3rd ed. *Cambridge: Cambridge University Press*, 236-285

Hill, M.K. (2004). Understanding Environmental Pollution. Second Edition. Cambridge University Press, New York.

Hossain, M.A., Hao Ngo, H., Guo, W.S., & Nguyen, T.V. (2012). Removal of copper from water by adsorption onto `banana peel as bioadsorbent. *International Journal of Geomate*, 2(2), 227-234.

Idris, S., Iyaka, Y.A., Dauda, B.E.N., Ndamitso, M.M., & Umar, M.T. (2012). Kinetic study of utilizing groundnut shell as an adsorbent in removing chromium and nickel from dye effluent. *American Chemical Science Journal,* 2(1), 12-24.

Ingale, S., Joshi, S.J., & Gupte, A. (2014). Production of bioethanol using agricultural waste: Banana pseudo stem. *Brazilian Journal of Microbiology*, 45(3), 885-892.

Inglezakias, V.J., Stylianou M.A.D., & Loizidou M.D. (2007). Removal of Pb (II) from aqueous solutions by using clinoptilolite and benzoate as adsorbents. *Desalination*, 210, 248-256.

Jacob, J. (2013). A Review of the Accumulation and Distribution of Persistent Organic Pollutants in the Environment. *International Journal of Biochemistry and Bioinformatics*, 3(6), 657-661.

Kabbashi, N.A., Elwathig, M., & Jamil, I.N. (2011). Application of activated carbon from empty fruit bunch (EFB) for mercury [Hg(II)] removal from aqueous solution. *African Journal of Biotechnology*, 10 (81), 18768 -18774.

Kanokkantapong, V., Marhaba, T. F., Panyapinyophol, B. & Pavasant, P. (2006). FTIR evaluation of functional groups involved in the formation of haloacetic acids during the chlorination of raw water. *Journal of Hazardous Materials*, 136(2), 188-196.

Keykavoos, R. (2012). Mineralization of bisphenol A by heterogeneous catalytic ozonation. *Master Thesis, University of Saskatchewan.*

Khan, S., He, X., Khan, J.A., Khan, H.M., Boccelli, D.L., & Dionysiou, D.D. (2017). Kinetics and mechanism of sulfate radical- and hydroxyl radical-induced degradation of highly chlorinated pesticide lindane in UV/peroxymonosulfate system. *Chemical Engineering Journal*, 318, 135-142.

Khan, S., He, X., Khan, J.A., Khan, H.M., Boccelli, D.L., & Dionysiou, D.D. (2016). Efficient degradation of lindane in aqueous solution by iron (II) and/or UV activated peroxymonosulfate. *Journal of Photochemistry and Photobiology A: Chemistry*, 316, 37-43.

Khattri, S. D., & Singh, M. K. (2009). Removal of malachite green from dye wastewater using neem sawdust by adsorption. *Journal of Hazardous Materials*, 167(1–3), 1089-1094.

Kiliç, M., Apaydin-Varol, E., & Putun, A.E. (2012). Preparation and surface characterization of activated carbons from Euphorbia rigida by chemical activation with $ZnCI_2$, K_2CO_3, NaOH, and H_3PO_4. *Applied Surface Science,* 261, 247-254.

Kong, J., Gu, R., Yuan, J., Liu, W., Wu, J., Fei, Z., & Yue, Q. (2018). Adsorption behaviour of Ni (II) onto activated carbons from hide waste and high-pressure steaming hide waste. *Ecotoxicology and Environmental Safety*, 156, 294-300.

Köseoğlu, E., & Akmil-Başar, C. (2015). Preparation, structural evaluation and adsorptive properties of activated carbon from agricultural waste biomass. *Advanced Powder Technology*, 26, 811-818.

Krishnamurthy, G., & Sona Bai, M. (2010). Oxidation of lindane in contaminated water under solar irradiation in the presence of photocatalyst and oxidizing agents. *Bulgarian Chemical Communications*, 42(2), 161-166.

Kumar, D., Kumar, A., & Sharma, J. (2016). Degradation study of lindane by novel strains Kocuria sp. DAB-1Y and Staphylococcus sp. DAB-1W. *Bioresources and Bioprocessing,* 3, 53–60.

Kumari, B., Madan, V.K., & Kathpal, T.S. (2008). Status of insecticide contamination of soil and water in Haryana, India. *Environmental Monitoring and Assessment*, 136, 239–244.

Kusvuran, E., & Yildrim, D. (2013). Degradation of bisphenol A by ozonation and determination of degradation intermediates by gas chromatography-mass spectrometry and liquid chromatography-mass spectrometry. *Chemical Engineering Journal*, 220, 6-14.

Kusvuran, E., Yildrim, D., Mavruk, F., & Ceyhan, M. (2012). Removal of chloropyrifos ethyl, tetradifon and chlorothalonil pesticide residues from citrus by using ozone. Journal of Hazardous Materials. 241-242, 287-300.

Lal, R., Pandey, G., Sharma, P., Kumari, K., Malhotra, S., Pandey, R., Lal, R., Pandey, G., Sharma, P., Kumari, K., Malhotra, S., Pandey, R., Raina, V., Kohler, H.P.E., Holliger, C., Jackson, C., & Oakeshott, J.G. (2010). Biochemistry of microbial degradation of hexachlorocyclohexane and prospects for bioremediation. *Microbiology and Molecular Biology Reviews,* 74 (1), 58-80.

Landeros, C.R., Díaz, C.E.B., Cháves, A.A., & Morales, G.R. (2017). Evaluation of a coupled system of electro-oxidation and ozonation to remove the pesticide Thiodan® 35 CE (endosulfan) in aqueous solution. *Fuel*, 198, 91-98.

Lata, S., & Samadder, S.R. (2016). Removal of arsenic from water using nano adsorbents and challenges: A review. *Journal Environmental Management*, 166, 387–406.

Laver, A. (2015). Hexachlorocyclohexane a well-known and highly explosive topic. Investigations on environmental levels of hexachlorocyclohexane in the Canton of Basel-Stadt. *University of Applied Sciences Northwestern Switzerland.*

Lazim, Z.M. (2016). Bisphenol A removal using chemical and physical treated agricultural waste. *Master Thesis, Universiti Teknologi Malaysia*.

Lee, Y.-M., Kim, K.-S., Jacobs Jr., D.R., & Lee, D.-H. (2017). Persistent organic pollutants in adipose tissue should be considered in obesity research. *Obesity Reviews*, 18, 129-139.

Liyan, S., Youcai, Z., Guojian, W., Bing, L., Dongjie, N., & Xioli, C. (2007). Biomimetic fat cell (BFC) preparation and for lindane removal from aqueous solution. *Journal of Hazardous Materials*, 146(1-2), 289-294.

Loredo-Cancino, M., Soto-Regalado, E., Cerino-Córdova, F.J., García-Reyes, R.B., García-León, A.M., & Garza-González, M.T. (2013). Determining optimal conditions to produce activated carbon from barley husks using single or dual optimization. *Journal of Environmental Management*, 125, 117-125.

Lutpi, N.A.A., Yuzir, M.A.M., Yong, E.L., Salim M.R., Yusop, Z., & Salmiati. (2015). The effect of water quality on removal of acetaminophen in surface water by ozonation process. *Jurnal Teknologi*, 74(11), 1-7.

Magriotis, Z.M., Leal, P.V.B., Sales, P.F., Papini, R.M., & Viana, P.R.M. (2010). Adsorption of etheramine on kaolinite: a cheap alternative for the treatment of mining effluents. *Journal of Hazardous Materials*, 184, 465-471.

Mahamad, M.N., Zaini, M.A.A., & Zakaria, Z.A. (2015). Preparation and characterization of activated carbon from pineapple waste biomass for dye removal. *International Biodeterioration and Biodegradation*, 102, 274-280.

Malakahmad, Amirhossein, Eisakhani, Mahdieh, & Kutty. (2009). GIS-based point and non-point sources of pollution identification in Cameron Highlands, Malaysia. *International Journal of Geological and Environmental Engineering*, 3(3).

Mall, I.D., Srivastava, V.C., & Agarwal, N.K. (2006). Removal of orange-G and methyl violet dyes by adsorption onto bagasse fly ash-kinetic study and equilibrium isotherm analyses. *Dyes Pigments*, 69, 210-223.

Mane, V.S., Mall, I.D., & Srivasta, V.C. (2007). Kinetic and equilibrium isotherm studies for the adsorptive removal of brilliant green dye from aqueous solution by rice husk ash. *Journal of Environmental Management*, 84, 390-400.

Maneerung, T., Liew, J., Dai, Y., Kawi, S., Chong, C., & Wang, C.-H. (2016). Activated carbon derived from carbon residue from biomass gasification and its application for dye adsorption: kinetics, isotherms and thermodynamic studies. *Bioresource Technology*, 200, 350–359.

Marsh, H., & Reinoso, F.R. (2006). Activated Carbon. *United Kingdom: Elsevier.*

Mishra, R.K., & Dubey, S.C. (2015). Fresh water availability and its global challenge. *International Journal of Engineering Science Invention Research & Development*, Vol 11, Issue VI.

Mohd Din, A.T., Hameed, B.H., & Ahmad, A.L. (2009). Batch adsorption of phenol onto physiochemical - activated coconut shell. *Journal Hazardous Material*, 161, 1522-1529.

Momcilovic, M., Purenovic, M., Bojic, A., Zarubica, A., & Randelovic, M., (2011). Removal of lead (II) ions from aqueous solutions by adsorption onto pine cone activated carbon. *Desalination*, 276, 53–59.

Mudoga, H.L., Yucel, H., & Kincal, N. (2008). Decolorization of sugar syrups using commercial and sugar beet pulp based activated carbons. *Bioresource Technology*, 99, 3528–3533.

Muñoz-Morales, M., Braojos, M., Sáez, C., Cañizares, P., & Rodrigo, M.A. (2017). Remediation of soils polluted with lindane using surfactant-aided soil washing and electrochemical oxidation. Journal of Hazardous Materials, 339, 232–238.

Murthy, H.M.R., Thakur, M.S., & Manonmani, H.K. (2010). Degradation of technical grade hexachlorocyclohexane in soil slurry by a defined microbial consortium. *International Journal Environmental Research*, 4(3), 471-478.

Naeem, A., Westerhoff, P., & Mustafa, S. (2007). Vanadium removal by metal (Hydr) oxide adsorbents. *Water Research*, 41(7), 1596-1602.

Nitoi, I., Oncescu, T., & Oancea, P. (2013). Mechanism and kinetic study for the degradation on lindane by photo-Fenton process. *Journal of Industrial and Engineering Chemistry*, 19(1), 305-309.

Njoku, V.O., Islam, M.A., Asif, M., & Hameed, B.H. (2015). Adsorption of 2,4-dichlorophenoxyacetic acid by mesoporous activated carbon prepared from H3PO4-activated langsat empty fruit bunch. *Journal of Environmental Management*, 154, 138-144.

Njoku, V.O., Islam, M.A., Asif, M., & Hameed, B.H. (2014). Utilization of sky fruit husk agricultural waste to produce high quality activated carbon for the herbicide bentazon adsorption. *Chemical Engineering Journal*, 251, 183-191.

Onal, Y., Akmil-Basar, C., & Sarici-Ozdemir, C. (2007). Elucidation of the naproxen sodium adsorption onto activated carbon prepared from waste apricot: kinetic, equilibrium and thermodynamic characterization. *Journal of Hazardous Materials*, 148(3), 727-734.

Örkün, Y., Karatepe, N., & Yavuz, R. (2012). Influence of temperature and impregnation ratio of H_3PO_4 on the production of activated carbon from hazelnut shell. *Acta Physica Polonica*, 121, 277–280.

Ormad, M.P., Miguel, N., Claver, A., Matesanz, J.M., & Ovelleiro, J.L. (2008). Pesticides removal in the process of drinking water production. *Chemosphere*, 71, 97-106.

Pamidimukkala, P.S., & Soni, H. (2018). Efficient removal of organic pollutants with activated carbon derived from palm shell: Spectroscopic characterisation and experimental optimisation. *Journal of Environmental Chemical Engineering*, 6, 3135-3149.

Pannu, R., & Kumar, D. (2017). Process optimization of γ-Hexachlorocyclohexane degradation using three novel Bacillus sp. strains. *Biocatalysis and Agricultural Biotechnology*, 11, 97-107.

Paul, D. (2017). Research on heavy metal pollution of river Ganga: A review. *Annals of Agrarian Science*, 15, 278-286.

Pavlíková, N., Bláhová, L., Klán, P., Bathula, S.R., Sklenář, V., Giesy, J.P., & Bláha, L. (2012). Enantioselective effects of alpha-hexachlorocyclohexane (HCH) isomers on androgen receptor activity in vitro. *Chemosphere*. 86, 65-69.

Perez, A.A., Sanchez, C.C., Rodríguez Patino, J.M., & Rubiolo, A.C. (2011). Surface adsorption behaviour of milk whey protein and pectin mixtures under conditions of air-water interface saturation. *Colloids Surfaces B Biointerfaces*, 85, 306-315.

Pezoti, O., Cazetta, A.L., Souza, I.P.A.F., Bedin, K.C., Martins, A.C., Silva, T.L., & Almeida, V.C. (2014). Adsorption studies of methylene blue onto ZnCl2-activated carbon produced from buriti shells (Mauritia flexuosa L.). *Journal of Industrial Engineering Chemistry*, 20(6), 4401–4407.

Phan, N.H., Rio, S., Faur, C., Le Coq, L., Le Cloirec, P., & Nguyen, T.H. (2006). Production of fibrous activated carbons from natural cellulose (jute, coconut) fibers for water treatment application. *Carbon*. 44, 2569-2577.

Philips, T.M., Seech, A.G., Lee, H., & Trevors, J.T. (2005). Biodegradation of hexachlorocyclohexane (HCH) by microorganisms. *Biodegradation*, 16, 363-392.

Pizzi & Nicholas, G. (2010). Water treatment-principles and practices of water supply operations. *Denver, CO: American Water Works Association*.

Rathore, H.S., & Nollet, L.M.L. (2012) Pesticides: Evaluation of Environmental Pollution. *CRC Press Taylor & Francis Group*.

Report on carcinogens (12th ed.). (2011). Lindane, hexachlorocyclohexane (technical grade), and other hexachlorocyclohexane isomers. *U.S. Department of Health and Human Services, Public Health Service*.

Román, I.S., Galdames, A., Alonso, M.L., Bartolomé, L., Vilas, J.L., & Alonso, R.M. (2016). Effect of coating on the environmental applications of zero valent iron nanoparticles: the lindane case. *Science of The Total Environment*, 565, 795-803.

Rosal, R., Rodríguez, A., Perdigón-Melón, J.A., Petre, A., García-Calvo, E., Gómez, M.J., Agüera, A., & Fernández-Alba, A.R. (2010). Occurrence of emerging pollutants in urban wastewater and their removal through biological treatment followed by ozonation. *Water Research*, 44, 578-588.

Saadati, N., Abdullah, M.P., Zakaria, Z., Rezayl, M., & Hosseinizare, N. (2012). Distribution and fate of HCH isomers and DDT metabolites in a tropical environment-case study Cameron Highlands, Malaysia. *Chemistry Central Journal*, 6, 130.

Saez, J.M., García, V.C., & Benimeli, C.S. (2017). Improvement of lindane removal by Streptomyces sp. M7 by using stable microemulsions. *Ecotoxicology and Environmental Safety*, 144, 351-359.

Salam, J.A.A., Lakshmi, V., Das, D., & Das, N. (2013). Biodegradation of lindane using a novel yeast strain, Rhodotorula sp. VITJzN03 isolated from agricultural soil. *World Journal Microbiology Biotechnology*, 29 (3), 475–487.

Salam, J.A., & Das, N. (2012). Remediation of lindane from environment: An overview. *International Journal of Advanced Biological Research*, 2, 9–15.

Saleh, T.A., Sari, A., & Tuzen, M. (2017). Effective adsorption of antimony (III) from aqueous solutions by polyamide-graphene composite as a novel adsorbent. *Chemical Engineering Journal*, 307, 230–238.

Sang, S., Petrovic, S., & Cuddeford, V. (2016). Lindane - A review of toxicity and envronmental fate. *Wildlife Toxicology Program, World Wildlife Fund Canada*.

Sangwan, N., Lata, P., Dwivedi, V., Singh, A., Niharika, N., Kaur, J., Anand, S., Malhotra, J., Jindal, S., Nigam, A., Lal, D., Dua, A., Saxena, A., Garg, N., Verma, M., Kaur, J., Mukherjee, U., Gilbert, J., Dowd, S., Raman, R., Khurana, P., Khurana, J., & Lal, R. (2012). Comparative metagenomic analysis of soil microbial communities across three hexachlorocyclohexane contamination levels. *PLoS ONE*, 7 (9): e46219. https://doi.org/10.1371/journal.pone.0046219.

Santana, G.M., Lelis, R.C.C., Jaguaribe, E.F., Morais, R.d.M., Paes, J.B., & Trugilho, P.F. (2017). Development of activated carbon from bamboo (Bambusa vulguris) for pesticide removal from aqueous solutions. *Cerne*, 23(1), 123-132.

Santos, A., Fenandez, J., Rodriguez, S., Dominguez, C.M., Lominchar, M.A., Lorenzo, D., & Romero, A. (2018). Abatement of chlorinated compounds in groundwater contaminated by HCH wastes using ISCO with alkali activated persulfate. *Science of The Total Environment*, 615, 1070-1077.

Santos-Clotas, E., Cobrera-Codony, A., Ruiz, B., Fuente, E., & Martin, M.J. (2019). Sewage biogas efficient purification by means of lignocellulosic waste-based activated carbon. *Bioresource Technology*, 275, 207-215.

Sathasivam, K., & Haris, M.R.H.M. (2010). Adsorption kinetics and capacity of fatty acid modified banana trunk fibres for oil in water. *Water, Air and Soil Pollution*, 213(1-4), 413-423.

Satish, G.P., Ashokrao, D.M., & Arun, S.K. (2017). Microbial degradation of pesticide: A review. *African Journal of Microbiology Research*, 11(24), 992-1012.

Schaider, L., Ackerman, J., Rudel, R., Dunagan, S., & Brody, J. (2011). Emerging contaminants in cape cod private drinking water wells. *Silent Spring Institute, Newton*.

Senthilkumaar, S., Varadarajan P.R., Potkodi, K., & Subbhuraam, C.V. (2005). Adsorption of methylene blue onto jut fibre carbon: Kinetics and equilibrium studies. *Journal Colloid Interface Science*, 284, 78-82.

Shabeer, T.P., Saha, A., Gajbhiye, V.T., Gupta, S., Manjaiah, K.M., & Varghese, E. (2014). Simultaneous removal of multiple pesticides from water: Effect of organically modified clays as coagulant aid and adsorbent in coagulation-flocculation process. *Environmental Technology*, 35 (17-20), 2619-2627.

Silva, L.A.D., Borges, S.M.S., Paulino, P.N., Fraga, M.A., Oliva, S.T.D., Marchetti, S.G., & Rangel, M.D.C. (2017). Methylene blue oxidation over iron oxide supported on activatedcarbon derived from peanut hulls. *Catalysis Today*, 289, 237-248.

Silvani, L., Cornelissen, G., & Hale, S.E. (2018). Sorption of α-, β-, γ- and δ-hexachlorocyclohexane isomers to three widely different biochars: Sorption mechanisms and application. *Chemosphere*, https://doi.org/10.1016/j.chemosphere.2018.12.070.

Šimkovič, K., Derco, J., & Valičková, M. (2015). Removal of selected pesticides by Nano zero-valent iron. *Acta Chimica Slovaca*, 8(2), 152-155.

Singh, S., Sherkhane, P.D., Kale, S.P., & Eapen, S. (2011). Expression of a human cytochrome P4502E1 in nicotiana tabacum enhances tolerance and remediation of γ-hexachlorocyclohexane. *New Biotechnology*, 28, 423-429.

Sivamani, S., & Leena Grace, B. (2009). Removal of dyes from wastewater using adsorption: A review. *Journal of Biosciences and Technology*, 2(4), 47-51.

Sousa, J.C.G., RIbeiro, A.R., Barbosa, M.O., Pereira, M.F.R., and Silva, A.M.T. (2018). A review on environmental monitoring of water organic pollutants identified by EU guidelines. *Journal of Hazardous Materials*, 344, 146-162.

Sousa, S., Jiménez-Guerrero, P., Rulz, A., Ratola, N., & Alves, A. (2011). Organochlorine pesticides removal from waste water by pine bark adsorption after activated sludge treatment. *Environmental Technology*, 32(5-6), 673-683.

Spiliotopoulou, A., Rojas-Tirado, P., Chhetri, R.K., Kaarsholm, K.M.S., Martin, R., Pedersen, P.B., Pedersen, L.F., & Andersen, H.R. (2018). Ozonation control and effects of ozone on water quality in recirculating aquaculture systems. *Water Research*, 133, 289-298

Subbaramaiah, P.V., Srivastava, V.C., & Mall, I.D. (2014). Catalytic oxidation of nitrobenzene by copper loaded activated carbon. *Separation and Purification Technology*, 125, 284–290.

Suhas, V.K., Gupta, P.J.M., Carroll, R., Singh, M., Chaudhary, S., & Kushwaha. (2016). Cellulose: A review as natural, modified and activated carbon adsorbent, *Bioresource Technology*, 216: 1066-1076.

Tan, X., Wan, Y., Huang, Y., He, C., Zhang, Z., He, Z., Hu, L., Zeng, J., & Shu, D. (2017). Three-dimensional MnO_2 porous hollow microspheres for enhanced activity as ozonation catalyst in degradation of bisphenol A. *Journal Hazardous Materials*, 321, 162-172.

Tay, K.S., Rahman, N.A., & Abas, M.R. (2012). Degradation of bisphenol A by ozonation: rate constants, influence of inorganic anions, and by-products. *Maejo International Journal of Science and Technology*, 6(01), 77-94.

Tham, Y.J., Latif, P.A., Abdullah, A.M., Shamala-devi, A., & Taufiq-Yap, Y.H. (2011). Performances of toluene removal by activated carbon derived from durian shell. *Bioresource Technology*, 102, 724–728.

Tor, A., Aydin, M.E., Aydin, S., Tabakci, M., & Beduk, F. (2013). Removal of lindane from an aqueous solution by using aminopropylsilica gel-immobilized calix [6] arene. *Journal of Hazardous Materials*, 262, 656-663.

Toxicological profile for alpha-, beta-, gamma-, and delta-hexachlorocyclohexane. (2005). Analytical methods. *U.S. Department of Health and Human Services, Public Health Service*.

Umar, M., Roddick, F., Fan, L., & Aziz, H.A. (2013). Application of ozone for the removal of bisphenol A from water and wastewater: A review. *Chemosphere*, 90, 2197-2207.

USDA. (1997). Code of federal regulations, title 9, part 381.66-poultry products; temperatures and chilling and freezing procedures. *Washington, DC: Office of federal register national archives and records administration*.

Vega, M., Romano, D., & Uotila, E. (2016). Lindane (Persistent Organic Pollutant) in the EU. Directorate General for Internal Policies. Policy Department C: Citizens' Rights and Constitutional Affairs. Petitions (PETI). PE 571.398.

Vijgen, J., Abhilash, P. C., Li, Y. F., Lal, R., Forter, M., Torres, J., Singh, N., Yunus, M., Tian, C., Schäffer, A., & Weber, R. (2011). Hexachlorocyclohexane (HCH) as new Stockholm Convention POPs-A global perspective on the management of lindane and its waste isomers. *Environmental Science and Pollution Research*, 18(2), 152-162.

Waclawek, S., Silvestri, D., Hrabák, P., Padil, V.V.T., Torres-Mendieta, R., Waclawek, M., Černik, M., Dionysiou, D.D. (2019). Chemical oxidation and reduction of hexachlorocyclohexanes: A review. *Water Research*, 162, 302-319.

Wang, C.W., & Liang, C. (2018). Reductive lindane degradation with tea extracts in aqueous phase. *Chemical Engineering Journal*. 338, 157-165.

Wanyonyi, W.C., & Onyari, J.M. (2013). Adsorption of Methylene Blue Dye from Aqueous Solutions Using Eichhornia crassipes. *Bulletin of Environmental Contamination and Toxicology*, 91(3), 362-366.

Wirasnita, R. (2015). Removal of bisphenol A from aqueous soution by adsorbing onto an activated carbon of the agricultural waste. *Master Thesis, Universiti Teknologi Malaysia*.

Wirasnita, R., Hadibarata, T., Yusoff, A.R.M., & Yusop, Z. (2014). Removal of bisphenol A from aqueous solution by activated carbon derived from oil palm empty fruit bunch. *Water Air Soil Pollution*, 225(2148), 1-12.

Wu, N., Zhou, B., Yan, H., Xu, S., Long, Y., and Liu, W. (2013). Determination of hexachlorocyclohexane (HCH) in panax ginseng of Chinese traditional medicine by gas chromatography /mass spectrometry. *Advanced Materials Research*, 830, 422-425.

Wu, J.G, Luan, T.G, Lan, C.Y, Lo, T.W.H., & Chan, G.Y.S. (2007). Removal of residual pesticides on vegetable using ozonated water. *Food Control*. 18, 466-472.

Yang, J., Tan, H., Zhai, H., Wang, Q., Zhao, N., Cai, Y., Li, M., & Zhou, H. (2011). Research on chemical composition and ensailing characteristics of banana stems and leaves. *Advanced Materials Research*, 347-353, 1647-1651.

Yao, Z.Y., Qi, J.H. & Wang, L.H. (2010). Equilibrium, kinetic and thermodynamic studies on the biosorption of Cu (II) onto chestnut shell. *Journal of Hazardous Materials*, 174(1–3), 137-143.

Yoon, Y., Westerhoff, P., Snyder, S.A., & Esparza, M. (2003). HPLC-fluorescence detection and adsorption of bisphenol A, 17β-estradiol and 17α-ethynyl estradiol on powdered activated carbon. *Water Research*, 37(14), 3530-3537.

Yu, J.G., Zhao, X.H., Yang, H., Chen, X.H., Yang, Q., Yu, L.Y., Jiang, J.H., & Chen, X.Q. (2014). Aqueous adsorption and removal of organic contaminants by carbon nanotubes: Review. *Science of the Total Environment*, 482–483, 241–251.

Yuen, F.K., & Hameed, B.H. (2006). Recent developments in the preparation and regeneration of activated carbons by microwaves. *Advances in Colloid and Interface Science*, 149(1-2), 19-27.

Zheng, G., Selvam, A., & Wong, J.W.C. (2011). Rapid degradation of lindane (g-hexachlorocyclohexane) at low temperature by Sphingobium strains. *International Biodeterioration & Biodegradation*, 65, 612-618.

Zhong, Z.Y., Yang, Q., Li, X.M., Luo, K., Liu, Y., & Zeng, G.M. (2012). Preparation of peanut hull-based activated carbon by microwave-induced phosphoric acid activation and its application in Remazol Brilliant Blue R adsorption. *Industrial Crops and Products*, 37, 178-185.

Zhou, S., B, L., Shi, Z., Bi, C., & Yi, Q. (2016). A novel advanced oxidation process using iron electrodes and ozone in atrazine degradation: Performance and mechanism. *Chemical Engineering Journal*, 306, 719-725.

Zhou, H.F., & Haynes, R.J. (2010). Sorption of heavy metals by inorganic and organic components of solid wastes: significance to use of wastes as low-cost adsorbents and immobilizing agents. *Critical Reviews Environmental Science and Technology*, 40, 909–977.

Zhou, Y., Chen, L., Lu, P., Tang, X., & Lu, J. (2011). Removal of bisphenol A from aqueous solution using modified fibric peat as a novel bio sorbent. *Separation and Purification Technology*, 81(2), 184-190.