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PHOTOCATALYTIC OXIDATION OF WASTE COOKING OIL USING ZEOLITE ZSM-5 & TiO_2 AS CATALYST: A PARAMETRIC OPTIMIZATION STUDY VIA RESPONSE SURFACE METHODOLOGY

Diyana Natasha Darimi[1] and Siti Khatijah Jamaludin[2]
[1]Faculty of Chemical Engineering, Universiti Teknologi MARA Pulau Pinang, 13500 Permatang Pauh, Pulau Pinang Malaysia
[2] Faculty of Chemical Engineering, Universiti Teknologi MARA Pulau Pinang, 13500 Permatang Pauh, Pulau Pinang Malaysia

sitikhatijah@uitm.edu.my

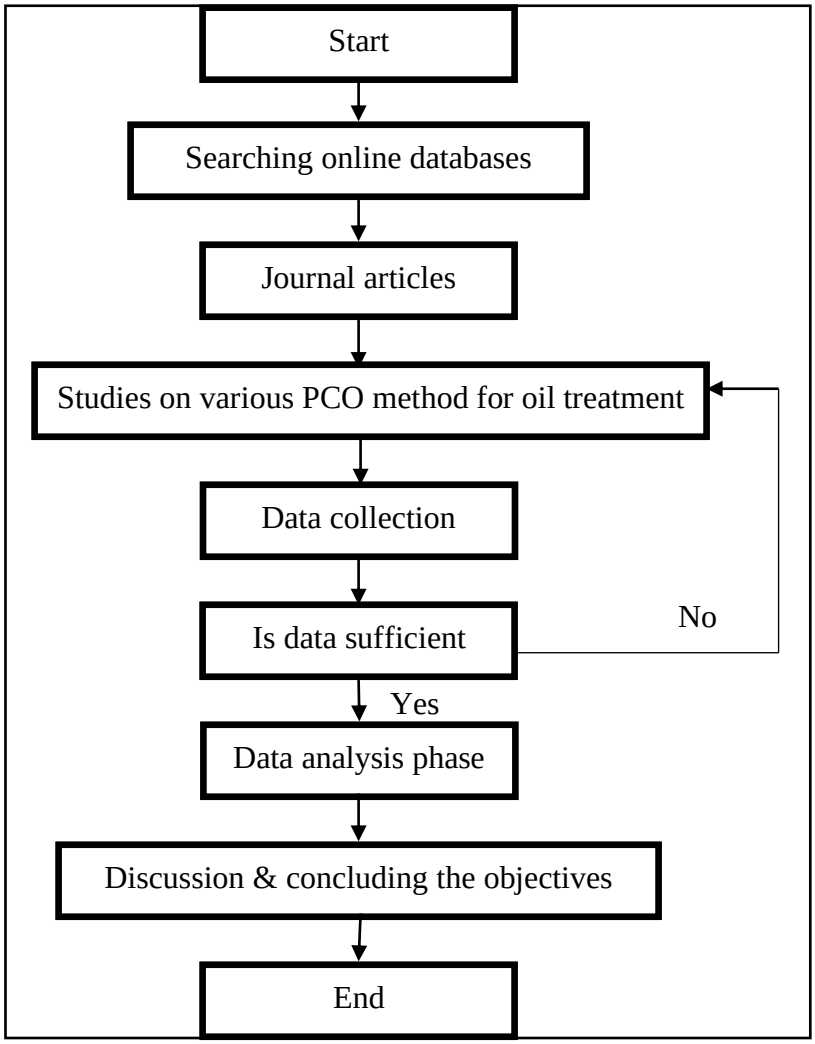
Abstract:
Waste cooking oil (WCO) are generated large scale all over the world, hence it has devised serious problems of its waste management which contributes to water pollution. There are variety of methods in order to treat WCO, which are by esterification, transesterification, recycle process and photocatalytic oxidation (PCO) technology process. Among all these three processes, PCO is the least applied for water treatment. It is because this process needs to use of catalyst in order to have high reactive of PCO reaction. This review study explores the PCO process using zeolite ZSM-5 and TiO_2 as catalyst. The aim of this study is to review on characterization of WCO and catalyst (TiO_2 and ZSM-5). Other than that, the main aim of this study is to review the optimization of reaction conditions such as pH of solution, reaction temperature, catalyst loading and type of catalyst used (TiO_2, ZSM-5) on the removal of WCO by using Response Surface Methodology (RSM). The review study presented here are based on literatures from year 2015 until present which were retrieved from databases such as Scopus, Research Gate and Science Direct. The results showed that, harmful organic molecules such as Free Fatty Acid (FFA) are contained in WCO as reviewed from Fourier-Transform Infrared Spectroscopy (FTIR) results. Brunauer-Emmett-Teller (BET) and Thermal Gravimetric Analysis (TGA) reviewed that ZSM-5 has high surface area and thermal stability which comparable to TiO_2 and other catalyst (Pt and Ag). The reviewed of various optimization studies via RSM shows that the optimum parameters are pH of solution (6-7), reaction temperature (30°C-50°C), catalyst dosage (0.1 g $100mL^{-1}$-0.3 g $100mL^{-1}$) and type of catalyst used (ZSM-5). In addition, some researcher proved that other factors such as light intensity and irradiation time are also important in PCO to treated WCO.

***Keywords*:**
Photocatalytic oxidation, Waste cooking oil, Zeolite ZSM-5 & Titanium dioxide catalyst, Parametric optimization, Response surface methodology.

Objectives:

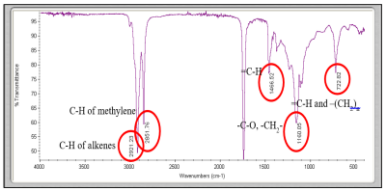
- To conduct a review on characterization studies of waste cooking oil (WCO) functional group and of catalyst (TiO_2, ZSM-5) surface area and thermal stability.
- To review the optimization of reaction conditions such as initial pH of solution, reaction temperature, catalyst dosage and type of catalyst used (TiO_2, ZSM-5) on the removal of waste cooking oil (WCO) by using RSM.

Methodology:



Results:

WCO - FTIR



ZSM-5 & TiO_2 - TGA & BET

Temperatures of calcination (°C)		400	500	600	700	800	900	Ref
Surface area (m^2g^{-1})	TiO_2	-	52.5	7.78	-	-	-	[74]
	ZSM-5	334	-	-	-	-	315	[75]
	Ag	-	6.7	-	4.8	-	-	[76]
	Pt	-	-	-	20.5	-	10.3	[77]

Initial pH of the solution

Organic pollutant	Initial pH solution	Removal oil efficiency (%)	Ref
Waste cooking oil (WCO)	Between 6 and 7	90	Naeem & Feng [15]
Waste cooking oil (WCO)	3 to 9	85	Nguyen [80]
Vegetable oil	3	80	Wang [81]
Olive oil	3	50	Umar [82]

Reaction temperature

Organic pollutant	Reaction temperature (°C)	Removal oil efficiency (%)	Ref
Waste cooking oil (WCO)	From 30 - 50	85	Yerkinova [23]
Waste cooking oil (WCO)	Below 80	82	Chen [85]
Vegetable oil	80	55	Gaya & Abdullah [79]
Olive oil	Between 20 - 80	60	Mohammed Haji [53]

Types of catalyst used

Organic pollutant	Catalyst used	Catalyst preparation	Removal oil efficiency (%)	Ref
Olive oil	ZSM-5	Hydrothermal process	-	Lovas [86]
Vegetable oil	TiO_2	Sol-gel method	-	Higashimoto [55]
Waste cooking oil (WCO)	ZSM-5	Aqueous reaction method	85	Mgbemere [28]
Waste cooking oil (WCO)	TiO_2	Sol-gel method	80	Yang [43]
POME	Ag	Sol-gel method	-	Torbina [77]
	Pt	Aqueous reaction method	65	Adriana [76]

Dosage of catalyst

Organic pollutant	Catalyst used	Catalyst Dosage	Removal oil efficiency (%)	Ref
Olive oil	TiO_2	0.1 – 0.4 g $100ml^{-1}$	60.2 - 83	Rahimi [87]
Vegetable oil	ZSM-5	0.35 – 0.4 g $100ml^{-1}$	70 - 50	Wei [89]
Waste cooking oil (WCO)	ZSM-5	0.1 – 0.3 g $100ml^{-1}$	70.95 - 92.49	Garcia [88]
Waste cooking oil (WCO)	TiO_2	0.8 g L^{-1}	85	Bukhari & Gonzalez [17][54]
POME	Ag	0.25 g L^{-1}	-	Torbina [77]
	Pt	0.5 g L^{-1}	-	Adriana [76]

Optimization - RSM

Organic pollutant	Initial pH solution	Reaction temperature (°C)	Type of catalyst used	Catalyst dosage	Removal oil efficiency (%)	Ref
Olive oil	3	20 - 80	ZSM-5	0.1 – 0.4 g $100ml^{-1}$	80	Arkedi [93]
Vegetable oil	3	80	TiO_2	0.35 – 0.4 g $100ml^{-1}$	60	Amiri [94]
Waste cooking oil (WCO)	6 - 7	30 - 50	ZSM-5	0.1 – 0.3 g $100ml^{-1}$	95	Zhang [91]
Waste cooking oil (WCO)	3	Below 80	TiO_2	0.8 g L^{-1}	85	Andullah [92]
POME	-	-	Ag	0.25 g L^{-1}	-	Torbina [77]
	-	-	Pt	0.5 g L^{-1}	65	Adriana [76]

Conclusion:

As conclusion, this review provides an overview of the wide range of photocatalytic activity to treat waste cooking oil (WCO). In general, photocatalytic oxidation process (PCO) is efficient, effective cost and environmentally friendly water and waste water treatment process. The study has confirmed the findings of Li et al. (2015) which found that waste cooking oil (WCO) is waste that need to be treated due to free fatty acid (FFA). FTIR resulted showed was C-H asymmetrical stretching in alkenes, C-H asymmetrical stretching in methylene, =C-H bending in methylene, -C-O and $–CH_2-$ bending and stretching in methylene groups and =C-H and $–(CH_2)_n$ bending in ester carbonyl functional group in fatty acid methyl ester. From TGA and BET reviewed studies found that ZSM-5 has high surface area and thermal stability which is comparable to TiO_2. This study has found that generally for optimization studied using RSM indicates that removal of oil best at initial pH solution range 6 and 7, reaction temperature 30°C to 50°C, catalyst dosage 0.1 g $100mL^{-1}$ to 0.3 g $100mL^{-1}$ and type of catalyst used ZSM-5 which up to 95% removal. Overall, the implementation of photocatalytic technological used to treated WCO known in Oleochemical industry indicates the considerable potential for future wide-scale adoption.