Renewable and Sustainable Energy Reviews 53 (2016) 741–753

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Progress in waste oil to sustainable energy, with emphasis on pyrolysis techniques

Su Shiung Lam [a,c,*], Rock Keey Liew [a], Ahmad Jusoh [a], Cheng Tung Chong [b], Farid Nasir Ani [b], Howard A. Chase [c]

[a] Eastern Corridor Renewable Energy Group (ECRE), Environmental Technology Programme, School of Ocean Engineering, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

[b] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

[c] Department of Chemical Engineering and Biotechnology, University of Cambridge, New Museums Site, Pembroke Street, Cambridge CB2 3RA, United Kingdom

ARTICLE INFO

Article history:
Received 21 January 2015
Accepted 14 September 2015

Keywords:
Waste oil
Used oil
Sustainable energy
Waste to energy
Pyrolysis
Microwave pyrolysis

ABSTRACT

This paper begins with a review on the current techniques used for the treatment and recovery of waste oil, which is then followed by an extensive review of the recent achievements in the sustainable development and utilization of pyrolysis techniques in energy recovery from waste oils. The advantages and limitations shown by the use of pyrolysis technique and other current techniques were discussed along with the future research that can be performed on the pyrolysis of waste oil. It was revealed that the current techniques (transesterification, hydrotreating, gasification, solvent extraction, and membrane technology) are yet to be sustainable or completely feasible for waste oil treatment and recovery. It was established that pyrolysis techniques offer a number of advantages over other existing techniques in recovering both the energetic and chemical value of waste oil by generating potentially useful pyrolysis products suitable for future reuse. In particular, microwave pyrolysis shows a distinct advantage in providing a rapid and energy-efficient heating compared to conventional pyrolysis techniques, and thus facilitating increased production rates. It was found that microwave pyrolysis of waste oil showed good performance with respect to product yield, reaction time, energy consumption, and product quality, and thus showing exceptional promise as a sustainable means for energy recovery from waste oils. Nevertheless, it was revealed that some important characteristics of the pyrolysis process have yet to be fully investigated. It was thus concluded that more studies are needed to extend existing understanding in the optimal reaction and process parameters in order to develop the pyrolysis technology to be a sustainable and commercially viable route for energy recovery from problematic waste oils.

Contents

* Corresponding author at: Eastern Corridor Renewable Energy Group (ECRE), School of Ocean Engineering, University Malaysia Terengganu , 21030 Kuala Terengganu, Terengganu, Malaysia. Tel.: +609 6683844; fax: +609 6683991.

E-mail addresses: lam@umt.edu.my, sushiung@gmail.com (S.S. Lam), lrklrk1991@gmail.com (R.K. Liew), ahmadj@umt.edu.my (A. Jusoh), ctchong@mail.fkm.utm.my (C.T. Chong), farid@mail.fkm.utm.my (F.N. Ani), hac1000@cam.ac.uk (H.A. Chase).

http://dx.doi.org/10.1016/j.rser.2015.09.005
1364-0321/

1. Introduction

Waste oils refer to contaminated or degraded liquid products that mainly consist of waste lubricating oil from machinery and cooking oil resulting from cooking operation. Waste lubricating oil is derived from engine oil, transmission oil, hydraulic, and cutting oils [1], whereas waste cooking oil is originated from cooking oil made from biological resources such as coconut, sunflower, soybean, palm tree, cottonseed, rapeseed, and olive.

Waste oils are well-known hazardous substances due to the presence of degraded additives and undesired substances that could bring about adverse impacts (e.g. carcinogenic, mutagenic, and reproductive effects) to human health and the environment (e.g. water and soil pollutions, frangible ecosystem, and climate changes). For cooking oil, its structure is altered by oxidation reaction via typical free radical mechanisms after an open air frying process. As a result, hydroperoxide is produced as a primary oxidation product and the hydroperoxide may further oxidize into very reactive and toxic products such as 4-hydroxy-2-alkenals [2], and thus making the waste cooking oil a hazardous waste [3]. The recycling of waste cooking oil as an animal feedstock is strictly prohibited in the European Union (EU) in order to prevent the carcinogenic components from transferring to the human body through food chain [4].

In 2010, the global consumption of lubricating oil was approximately 42 million tons and it is forecasted to hit 45 million tons by 2015 [5]. Due to the imperfection of machinery efficiency, about 50% of the lubricating oil ended up as waste lubricating oil after the operations and this resulted in the generation of 20 million tons of waste oil. Up to 30% of the generated waste oil was derived from Asia, whereas North America had contributed about 22% of the waste oil [5]. In addition, the EU has gobbled up 6 million tons of lubricating oil in 2006 and in turn producing 3 million tons of waste lubricating oil to be disposed of [6]. On the other hand, waste cooking oil is also present as a problematic waste oil. The continual increase in human population will ensure a continuous food demand and consequently an inevitable generation of waste cooking oil. According to the estimation of global edible oil consumption from the U.S. Census Bureau, International Data Base, Internal Estimates (USDA), there are 145 million tons of edible oil being consumed in 2012 and it is expected to reach 660 million tons by 2050 from which palm oil ranks as the highest demand by the world population [7]. Stevens [8] reported that catering and industrial sources in the UK have been synthesizing about 50,000 and 100,000 t of waste vegetable oil annually, respectively. Moreover, there is an approximately 1 million ton of waste cooking oil being produced from French fries and snack food industries every year in the EU [9]. Thus, the increasing generation of waste oil in high volume has become a major concern for modern society.

The disposal of waste oil is a major challenge nowadays as the improper disposal of this hazardous waste could pose a direct hazard to the environment and human health. On account of the high management cost needed for the disposal of waste oil, illegal dumping of waste oil into the sewers and the sea could be the normal practice by irresponsible generators of waste oil and even by unsupervised government authorities. The discharge of waste oil into the ocean could endanger the marine life, especially the seabirds where the waste oil could adsorb on their feathers and in turn disable their delicate hooks and barbs that are usually functioned as a protection of their skin from long-term exposure to water, thus making the seabirds vulnerable to cold water and eventually causing their death from hypothermia [10]. Additionally, the hydrophobic nature of waste oil could create a layer of oil on the surface of the water that could inhibit the oxygen dissolution and leading to an increase of the chemical oxygen demand (COD) levels in the water [9]. Recently, the dumping of waste cooking oil into the sewers has created a serious problem that has become a public concern in China and Taiwan. It was revealed that some greedy and heartless companies are making huge profits by converting the waste hogwash oil collected from the sewers into cooking oil using only simple treatment procedures; the waste hogwash oil refers to the waste oil disposed from the processing and frying of waste animal parts and organs [11]. The 'badly-refined' cooking oil, containing undesirable substances such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals (e.g. nickel and lead), is then released to the market and sold to restaurants at a cheap price, and in turn poisons the customers who have eaten the food cooked with the 'badly-refined' cooking oil in those restaurants [12]. Another common disposal of waste oils is by incineration. Incineration results in the release of greenhouse gases (e.g. CO_2) that contributes to climate changes. Moreover, this method also leads to toxic emission of flue gas containing PAHs, fly ash, and dangerous polychlorinated compound [13].

Owing to the problematic nature of waste oils that could cause a series of negative chain reactions to human health and the environment, the development of an environmentally safe, sustainable, socially acceptable, and cost-effective solution should be taken as a primary consideration for the treatment, recovery, and disposal of waste oil [14]. There are some techniques that have been exploited in order to tackle the problems derived from the disposal of waste oil and to formulate the feasibility and sustainability of waste to energy conversion [15]. Waste to energy is an energy recovery application that employs waste processing technologies to produce energy or valuable materials from waste materials (e.g. biomass, plastics, waste oils, and sewage sludge). This review presents and discusses the current methods used for the treatment and recovery of waste oil. Then, emphasis is focused on the sustainable development and utilization of pyrolysis techniques in waste oil recovery. The advantages and limitations shown by the use of pyrolysis technique and other current techniques are presented and discussed along with the future research directions.