Journal of Hazardous Materials 359 (2018) 454–464

Contents lists available at ScienceDirect

Journal of Hazardous Materials

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

Pyrolysis of textile dyeing sludge in fluidized bed and microwave-assisted auger reactor: Comparison and characterization of pyrolysis products

Yang Liu[a,b], Chunmei Ran[a,b], Azka Rizwana Siddiqui[a,b], Xiao Mao[a,b], Qinhao Kang[a,b], Jie Fu[a,b], Zeyu Deng[a,b], Yongmeng Song[a,b], Zhihui Jiang[a,b], Tianhao Zhang[a,b], Jianjun Dai[a,b,*]

[a] College of Chemical Engineering, Beijing University of Chemical Technology, 15 Beisanhua East Road, Chaoyang District, Beijing, 100029, China

[b] State Key Laboratory of Organic-Inorganic Composites, Beijing University of Chemical Technology, 15 Beisanhua East Road, Chaoyang District, Beijing, 100029, China

ARTICLE INFO

Keywords:
Textile dyeing sludge
Fluidized bed
Microwave
Auger
Pyrolysis

ABSTRACT

This paper investigated fluidized bed pyrolysis (FBP) and microwave-assisted auger pyrolysis (MWAP) for treatment and disposal of textile dyeing sludge (DS), and the products were analyzed and compared. MWAP achieved higher yields of char and condensate, and lower non-condensable gas yields compared to FBP. The yields of CO_2 from FBP were much higher than those from MWAP at 450–850 °C. Whereas the yields of H_2, CO and CH_4 from MWAP were greater than those from FBP at higher temperature (e.g. 850 °C). The maximum condensate yields of FBP and MWAP were observed at 650 °C. Pyrolysis oil of MWAP contained less of macromolecules compared to FBP. Pyridine, phenol, aniline and their derivatives were major components in MWAP oil. Pyridine was the dominant oil component at 850 °C for FBP. Most of nitrogen-, sulfur- and chlorine-containing compounds were retained in FC (FBP char) and MC (MWAP char), and higher relative proportion (RP) of nitrogen, sulfur and chlorine were observed in the condensate and non-condensable gas from MWAP in comparison with FBP. FBP and MWAP both decreased risk degrees of heavy metals compared to raw DS, and heavy metals in FC and MC posed slight risk to the environment based on national standards in China.

1. Introduction

The discharge rate of industrial sludge has been increasing in the past decades in China, mainly due to rapid economy and industry development. It was estimated that 17–20% of water pollution in industries was caused by pollutants from textile dyeing sectors in the world [1]. The discharge amount of wastewater from textile dyeing industries is about 2.1 billion tonnes and about 21 million tonnes of textile dyeing sludge (DS) are created each year in China. DS is categorized into hazardous industrial wastes, and ash content of DS is high and even up to more than 60 wt% (oven-dry basis). DS has very complex chemical compositions, and usually contains more toxic organic matter (e.g. dyes, additives, microorganisms, polycyclic aromatic hydrocarbons-PAH), and heavy metals (e.g. zinc, copper, lead, chromium) than sewage sludge. Improper treatment and disposal of DS has caused serious environmental problems [2–4]. In recent years, pyrolysis and gasification were developed to treat sludge of different sources and properties due mainly to their advantages such as fast reaction rate, small footprint, high efficiency, reduced emissions under oxygen-deficient reaction environment, flexibility to fuel properties, ease of control and scale-up. Both pyrolysis and gasification are excellent candidates for processing various solid wastes and are more efficient and cleaner in comparison with combustion [5–9].

Pyrolysis in the fluidized bed can realize rapid pyrolysis and it is favorable for formation and release of volatiles and oil vapors [10]. Fluidized bed reactors are relatively simple to construct and operate, and have been widely used in various applications as they have good temperature control and high heat transfer rate [11,12]. It is possible to carry out very efficient heat transfer to the particles because of the high concentration of solids in the fluidized beds [13]. Soria-Verdugo et al. [14] studied the pyrolysis of the sewage sludge in a fixed bed. It showed that increasing the gas (i.e. N_2) velocity of a fixed bed (i.e. 0.8 U_{mf}) to a value of 2.5 times minimum fluidization velocity (i.e. 2.5 U_{mf}) accelerated the pyrolysis processes significantly, reducing the pyrolysis time. The University of Waterloo in Canada initiated a fluidized bed pyrolysis project to produce bio-oil with a capacity of 100 tons/day [15,16]. Arazo et al. [17] investigated the optimization of bio-oil from fast pyrolysis of sewage sludge in a fluidized bed pyrolyser. The pyrolysis treatment of oily sludge was studied by Qin et al. [18] in a fluidized bed in the temperature range of 400–600 °C. However, few

* Corresponding author.
E-mail addresses: jjdai@mail.buct.edu.cn, 2016200225@mail.buct.edu.cn, 2016200224@mail.buct.edu.cn (J. Dai).

https://doi.org/10.1016/j.jhazmat.2018.07.055
Received 23 March 2018; Received in revised form 9 June 2018; Accepted 11 July 2018

Nomenclature

CH	Conventional heating
MWAP	Microwave-assisted auger pyrolysis or pyrolyser
DS	Textile dyeing sludge
MWH	Microwave heating
FBP	Fluidized bed pyrolysis or pyrolyser
MC	MWAP char
FC	FBP char
MWA	Microwave absorber
FTIR	Fourier transform infra-red spectroscopy
RP	Relative proportion
GC	Gas chromatography
U_{mf}	Minimum fluidization velocity
GC–MS	Gas chromatography mass spectrometry
U_{mb}	Minimum bubbling velocity
ICP-MS	Inductively coupled plasma mass spectrometry
U_t	Terminal settling velocity
MW	Microwave
XRF	X-ray fluorescence

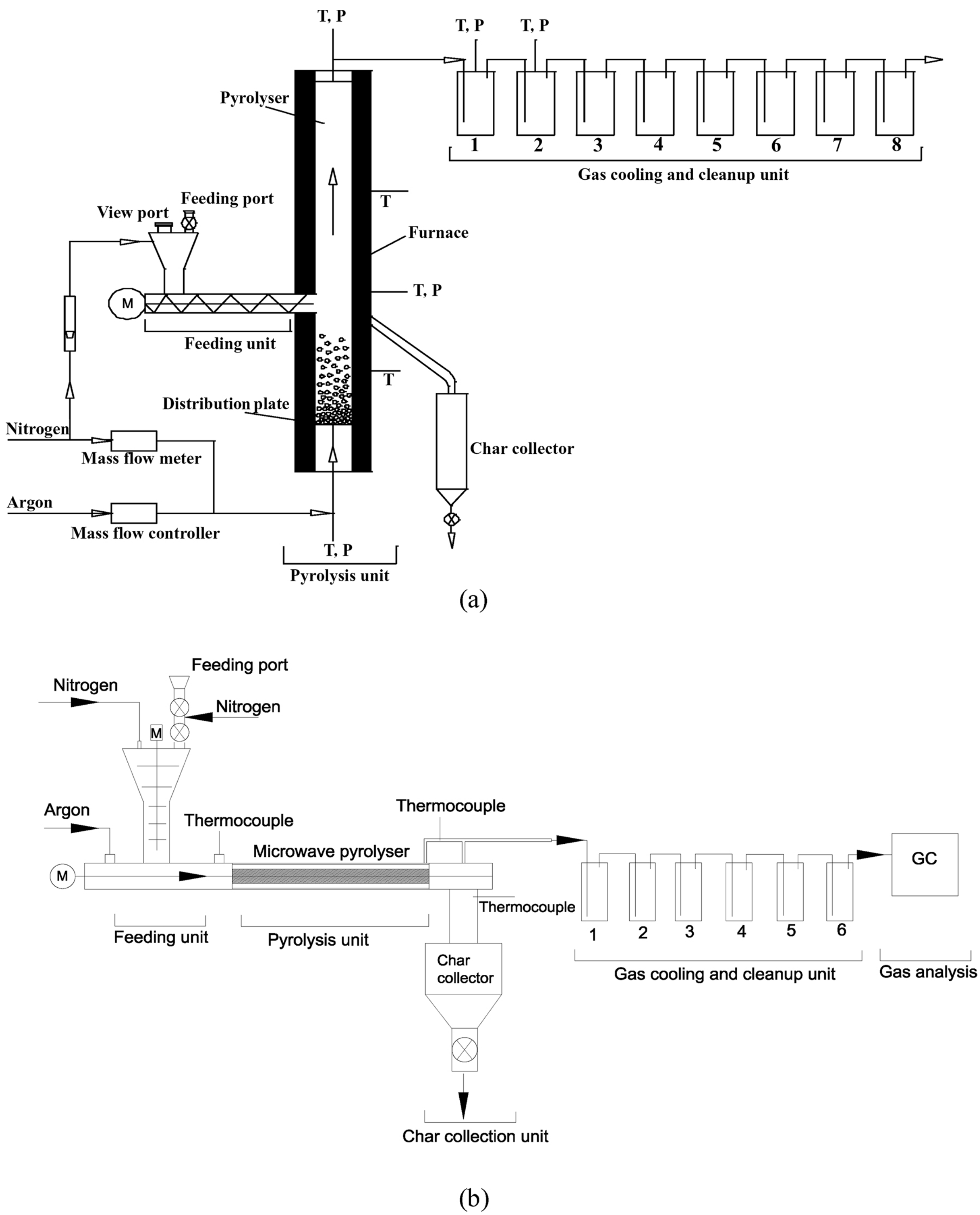

Fig. 1. A schematic diagram of (a) fluidized bed pyrolyser and (b) microwave-assisted auger pyrolyser.