Chapter 5
Advanced Oxidation Processes (AOPs) to Treat the Petroleum Wastewater

Dheeaa al deen Atallah Ali
University Sains Malaysia, Malaysia

Puganeshwary Palaniandy
University Sains Malaysia, Malaysia

Shaik. Feroz
Caledonian College of Engineering, Oman

ABSTRACT

Petroleum wastewater generation is one of the main pollutants associated with oil refineries processes. The petroleum wastewater usually contains a complex variety of materials and organic compounds. Dedicated treatment facilities are required before the petroleum wastewater can be discharged to the environment. Researchers worldwide are still searching for a total solution to solve petroleum wastewater problem. In this chapter, different chemical treatment methods for the petroleum wastewater including coagulation-flocculation, Fenton and electro-Fenton oxidation, photocatalyst oxidation, and advanced oxidation processes are reviewed and discussed. Nevertheless, the efficiency of each process was also evaluated. It can be concluded that the performance of these processes is mainly attributed to petroleum wastewater type and initial organic concentrations whereas treatment performance weakens reported at higher initial concentrations of pollutants.

INTRODUCTION

The petroleum wastewater is a complex organic liquid and can have enormously adverse environmental impacts, depending on the characteristics of the materials, which exist in them. In general, the pollutants in wastewater can be divided into organic matters and inorganic matters, which included nitrogen, phosphorus, ammonia and iron chlorides as well as heavy metals (Tengrui et al., 2007). A large amount

DOI: 10.4018/978-1-5225-5766-1.ch005

of water is used during the petroleum refinery activity. Consequently, significant volumes of wastewater are generated.

Advanced oxidation processes (AOPs) have a capability of rapid degradation of recalcitrant pollutants in the aquatic environment. They have shown high efficiency to remove the organic compounds from effluents even when they are present in low concentrations (Silva et al., 2015; Masomboon et al., 2010; Paz et al., 2013; Philippopoulos & Poulopoulos, 2003) and did not form environmentally dangerous byproducts (Giri & Golder, 2014). A remediation of hazardous substances is attributed to hydroxyl radical ($^{\cdot}OH$), which exhibits reactivity toward organic compounds and has the potential to destroy and degrade them (Hermosilla et al., 2009). Many techniques are used to enhance the production rate of hydroxyl radicals by chemical additives (such as hydrogen peroxide (H_2O_2)), external energy (such as sunlight), catalysts (such as titanium dioxide (TiO_2)) and the integration of two or more AOPs (such as TiO_2/Fenton/sunlight) (Kim et al., 2012). Using solar energy in the AOPs could reduce processing costs and make the AOPs more affordable for commercial use (Amor et al., 2015). AOPs might be used in wastewater treatment for reduction of chemical oxygen demand (COD), color, odor and specific pollutant or sludge treatment (Amor et al., 2015; Tony et al., 2012).

The photocatalyst is a promising technique for the treatment of contaminated water, which has been widely studied during recent years because it is fast, effective, eco-friendly, economically viable, and able to completely oxidize organic molecules at a low energy (Kwon et al., 2008). When TiO_2 is exposed to sunlight, a hole in the valence band and an electron in the conduction band are generated by light induction. This hole causes the oxidation of hydroxyl ions and produces the hydroxyl radicals at the TiO_2 surface while in the solar photo-Fenton process, the formation of hydroxyl radicals bases on the reaction between Fe^{+2} and H_2O_2 under sunlight irradiation. The photocatalyst processes have shown promising results in the treatment of non-biodegradable and toxic compounds (Boundjou et al. 2012). The major drawbacks of Fenton process are iron complexation by carboxylic intermediates. However, these complexes could be photoactivated by the photo-Fenton process and additional hydroxyl radicals ($HO^{\bullet}$) generation (Amor et al., 2015). The solar photo-Fenton is based on using solar radiation to increase production of hydroxyl radicals ($HO^{\bullet}$) and photoactive complexes through the Fenton process (Amor et al., 2015; Fernandes et al., 2014; Lucas et al., 2012; Pignatello et al., 2006).

Petroleum Wastewater Characteristics

The typical characteristics of the petroleum wastewater are shown in Table 2.1. Oil, grease, phenolic compounds, nitrogen, and sulphur components are mainly the compounds that are present in petroleum wastewater (Abdelwahab et al., 2009; Kavitha & Palanivelu, 2004; Lathasree et al., 2004; Pardeshi & Patil, 2008; Yang, 2008).

The oil and grease in the petroleum wastewater are sticky and can clog drain pipes. They also cause unpleasant odors and capable of corroding drain pipes (Xu & Zhu, 2004). The phenolic compounds is a threat to the environment due to their extreme toxicity and ability to remain for long periods in the environment (Abdelwahab et al., 2009; Kavitha & Palanivelu, 2004; Lathasree et al., 2004; Pardeshi & Patil, 2008; Yang, 2008). The nitrogen and sulphur components in the petroleum wastewater are represented in the form of ammonia and hydrogen sulphide (H_2S), respectively (Altaş & Büyükgüngör, 2008). In addition, Naphthenic acids (NAs) are one class of compounds in wastewaters from petroleum industries that are known to cause toxic effects, and their removal from oilfield wastewater is an important challenge for remediation of large volumes of petrochemical effluents (Wang et al., 2015). Due