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FULL LENGTH ARTICLE

A novel approach for reduction of total acidity in kerosene based on alkaline rich materials readily available in tropical and sub-tropical countries

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Abstract The inability of refineries in some nations globally to produce kerosene locally as an aviation fuel is due to its acidity. In this study the viability of selected alkaline rich ash materials (e.g. cocoa husk, cassava peels, etc.) readily obtainable in tropical nations were examined for their ability to remove the acids. Fresh acidic kerosene samples were equilibrated with different ashes in predetermined ratios, filtered and characterized alongside with non-treated reference samples. Results revealed that the physicochemical properties of non-treated and treated kerosene remained the same except for conductivity, total acidity and micro-separation. The total acidity was reduced to a lowest limit than 0.015 mg KOH/g required. Treatment studies with specific masses of ashes and kerosene reduced acidity to approximately 0.00 mg KOH/g. Overall these alkaline source materials should be seen as a promising and alternative option in the systematic reduction of acidity in kerosene for aviation use.

1. Introduction

Crude oil, petroleum, is a naturally occurring flammable liquid consisting of a complex mixture of hydrocarbons, comprising of liquefied petroleum gas (LPG), gasoline, kerosene, gas oil, etc. which are all energy sources. Kerosene, a fractional distillate (150–260 °C), constitutes one of the most important fuels mainly used for powering jet engines and to a lesser extent for domestic purposes [1,2]. Accordingly, kerosene is labelled as dual purpose kerosene (DPK). DPK can only be used as aviation fuel if it meets very stringent international standard specifications. Currently, aviation fuel is almost exclusively extracted from the kerosene fraction of crude oil, including

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both jet fuel for turbine engines and aviation gasoline for piston engines [3].

There are many different kinds of crude oil however, the cheapest and readily available are usually known to contain a high amount of acids [4] and hence when processed produces acidic kerosene which cannot be used as aviation turbine kerosene (ATK), a big worry among nations the world over, including Ghana. The acidic compounds found in kerosene fractional distillate which contribute to higher total acidity value are naphthenic acids, cresylic acids, mercaptans and hydrogen sulfides [5]. Thus the higher the acidity of crude oil, the higher the total acidity content of kerosene produced. This ultimately also affects the usage of kerosene as aviation fuel, as these acids tend to corrode the jet engines. Prominent among the acids that add to the total acidity of kerosene are naphthenic acids. Crude oil contains varied amounts of these acids possessing high corrosive potential toward metals under certain conditions, and therefore, is very treacherous to the aviation industry [3,6].

Naphthenic acids occur in a wide boiling range of crude oil fractions, 180–380 °C of kerosene or ATK, and diesel fractions, and are generally concentrated within petroleum distillates of boiling temperatures between 200 °C and 370 °C. Naphthenic acid corrosion control can be attained by various mitigation measures including pre-distillation and removal of naphthenic acids from the crude oil being processed; blending of acidic with non-acidic crude oils [7] or distilled fractions; neutralization by injection of soda or other neutralizers; use of corrosion inhibitors; and coatings, and limiting of fluid flow [1]. Caustic washing removes acidic components of the petroleum fractionate, including phenol and cresols (cresylic acid). In addition to reducing corrosion in the refinery, the caustic wash also improves the burning qualities, storage stability, and odor of the finished kerosene and diesel fuels. Besides the high cost of the caustic technology, there also exists some challenges relating to separation of the aqueous caustic phase from the organic kerosene phase [5]. These challenges have caused some refinery industries to resort to reliance on the type of crude which are free of acids or contain a minimal amount of acids, for example, sweet crude oil, light crude oil, etc. with the belief that kerosene produced from such crude brands through fractional distillation processes would meet the international standards for ATK. Non-caustic processes for the removal of naphthenic acids from petroleum distillates, including ammonia, triethylene glycol, ion-exchange resins, and aluminosilicate zeolites, have also been reported though not commercialized [4].

In view of these acids present in crude oil, refineries are constantly exploring diverse ways of removing or lowering the acidic content of petroleum products such as aviation kerosene to minimize the cost of production. Various methods have being explored viz absorption, extraction or destruction of naphthenic acids [1,8–10]. Despite these, many nations including Ghana are suffering because periodically the kerosene produced does not meet aviation fuel strict standards; hence kerosene is most often used for domestic purposes resulting in periodic shortages. This does not augur well for the aviation industry and businesses. Accordingly, there is the need for investigation into efficient and cheaper alternatives that can reduce acidity in petroleum refinery kerosene to the lowest levels.

For instance, Ghana produces high tonnage of dual purpose kerosene (DPK). Information from the Tema Oil Refinery (Ghana) indicates that out of 3500 metric tons of crude oil processed per day, 15% comes as DPK, about 648,000 L/day. The demand for aviation turbine kerosene on the Ghanaian market per month is about 12,000,000 L and that of domestic kerosene is about 5,000,000 L [11]. Unfortunately, there has been perennial shortages of kerosene particularly, aviation fuel, thus having adverse effects on both people and businesses in diverse ways. These shortages are as a result of Ghana's only refinery inability to supply kerosene to meet international standard requirements due to high acidic levels (predominantly naphthenic acids) which could also recur in other nations as well. However, the refinery's inability to reprocess the distilled DPK to obtain ATK is as a result of the highly expensive nature of the caustic treatment process. Hence, the kerosene produced is eventually converted to domestic use whose demand is far lower than the aviation industry.

Incidentally, most of the low-priced and readily available crude oil on the world market contains higher levels of acidity values which are beyond standard limits. In this work, focus is placed on lowering the total acidity (naphthenic acid, cresylic acids, etc.) content of kerosene via cheaper sources of alkaline/base materials, specifically ash, obtained from cocoa husk, coconut husk, plantain heels and cassava peels. These materials are all good candidates for washing kerosene to reduce acidic content. The maximum standard total acidity value of kerosene for aviation usage is currently 0.015 mg KOH/g as specified by the international standards [12].

2. Experimental

2.1. Sample collection

Apparently these source materials are very common, less in demand and readily obtainable in most tropical and subtropical countries like Ghana. In this case, the ash source materials including plantain peels, cassava peels and coconut husk were collected from Tema (Greater Accra Region), Kasoa and Bawjiase markets (Central Region). Cocoa husks and leaves were collected from Buoyem and Techiman (Brong Ahafo Region) Fig. 1. For kerosene, five fractional distillates (13 L each) from five different crude oil sources namely Bonny-light crude oil (Nigeria), Forcados crude oil (Nigeria), Coco crude oil (Congo), Medanito crude oil (Argentina) and crude oil blend were obtained from the Tema Oil Refinery Ltd (Ghana). All samples were collected in duplicates during the period of study, 2011–2012.

2.2. Chemicals, reagents, analytical equipment

All chemicals used were of analytical grade. Toluene, concentrated nitric acid (HNO_3 63.01% v/v), *p*-naphtholbenzein and fluorescent indicator solutions were obtained from BDH (VWR International Ltd, Poole, BH15 1TD, England). Iso-octane and propan-2-ol were obtained from Alpha Chemika, Mumbai-400 002, India. Potassium hydroxide pellets (KOH) and barium hydroxide [$Ba(OH)_2$] powder from Analar