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Physicochemical characterization of the Jubilee crude oil

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ABSTRACT

The physicochemical parameters and some contaminants of crude oil samples from the Jubilee oil field at Cape Three Points, western region and Saltpond oil field in Central region of Ghana were analyzed to classify and assess the quality of the crude oils. The physicochemical parameters determined were density, specific gravity, API, pour point, total sulphur content, salt in crude, total acid number, viscosity, reid vapour pressure and ash weight whereas the contaminants measured were water and sediments. Results from the physicochemical parameters for both samples showed a perfect Pearson's correlation ($r \approx 1$). Low water and sediments levels (<1%) were recorded for both crude oils. This is an indication of low or minimal microbial growth and reduced ability of both crude oils to serve as a collector of water soluble metals and salts. This enhances the quality of the crude oils making them less fouling and corrosion resistant at high temperatures. High API values (API>30), coupled with low specific gravity, viscosity and pour point for both crude oils make them light crude oils. The sulphur concentration for both samples were low and within globally accepted range of 0.1-0.5 wt. % for sweet crude oil.

Introduction

Crude oil exploration in Ghana started as early as 1896 with wells being drilled in the vicinity of Half-Assini as a result of oil seeps found in the onshore Tano Basin in the Western Region of Ghana. The Saltpond field was discovered in 1970 following the drilling of the Signal Amoco Well approximately 100 km west of Accra. Over the past ten years, exploration for commercial hydrocarbons in Ghana has intensified with major success achieved with the Jubilee, Odum, Tweneboa and Owo (renamed Enyenra) fields at cape three points. While most of these fields and more; Mahogany, Wawa, Ntomme, Akasa, Teak, are still being developed, the Jubilee field, discovered in June 2007, begun phased oil production in December, 2010 with a current yearly output range of 70,000 to 90,000bpd and a targeted plateau output of about 120,000bpd by 2013. [3-5].

Since crude oil is not homogenous and its characteristics vary widely from oilfield to oilfield, well to well in the same oilfield, depth of well and year of production , there is the need to study its physicochemical properties[1]. Similarly oils that are transported are often blends of different crude oils, and the relative proportions of component oils frequently change, therefore, the physical and chemical properties will vary.

Over the years, the chemical utilization of crude oil has been on the increase globally. As a result, concerted efforts are being made to understand its composition, structure and properties [2]. The knowledge of physicochemical parameters of crude oils has been used widely in many applications: quality assessment, classification and environmental behavior monitoring and effects. Important property like viscosity affects the rate at which spilled oil will spread, the degree to which it will penetrate shoreline substrates, and the selection of mechanical spill countermeasures equipment. An extensive laboratory investigation of crude oil properties when exposed to weathering was used by Brandvik et al [6] for predicting the behaviour of oil spilled on the sea. Physical and chemical properties were used to recover crude oil from oil-saturated rubber particles [7]. The quality of many petroleum products is related to the amount of sulfur present [8]. The price of a crude oil is usually based on its API gravity, with high gravity oils commanding higher prices.

In this paper, we present the physicochemical parameters of the Jubilee and Saltpond fields crude oil. Parameters studied include density/specific gravity/API, pour point, total sulphur, salt in crude, total acid number, viscosity, reid vapour pressure, water content, ash weight and sediments.

Geographical description of the source of crude oil

The Jubilee and Saltpond oil fields are located in the gulf of Guinea (figs 1 and 2). Details of these fields have been published elsewhere [11].

Materials and Methods

Crude oil samples

Samples of the Saltpond and Jubilee crude oils were obtained from Tema Oil Refinery (TOR) and Ghana National Petroleum Corporation (GNPC) respectively. The Jubilee crude oil is a composite of oils pumped from different wells within the Jubilee field. It was pumped in sessions at different times, starting from December 2010. Samples of the Jubilee crude oil used for this analysis were the 5th composite, obtained in March 2011[3-5]

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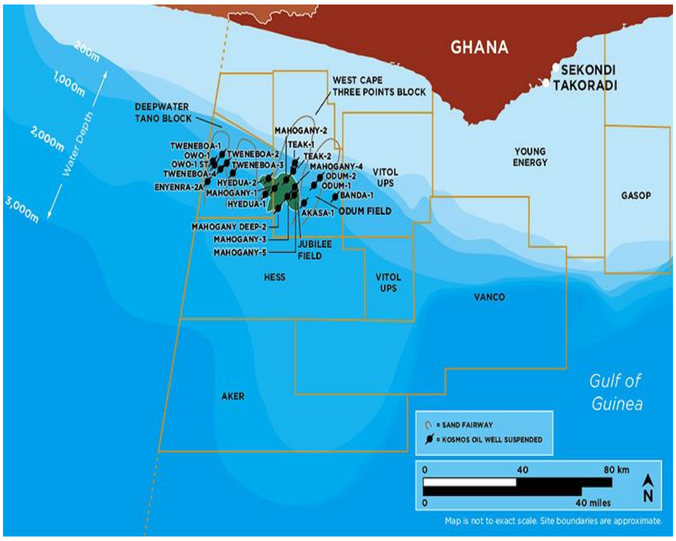

Fig 1. Jubilee field straddling the two oil concession blocks

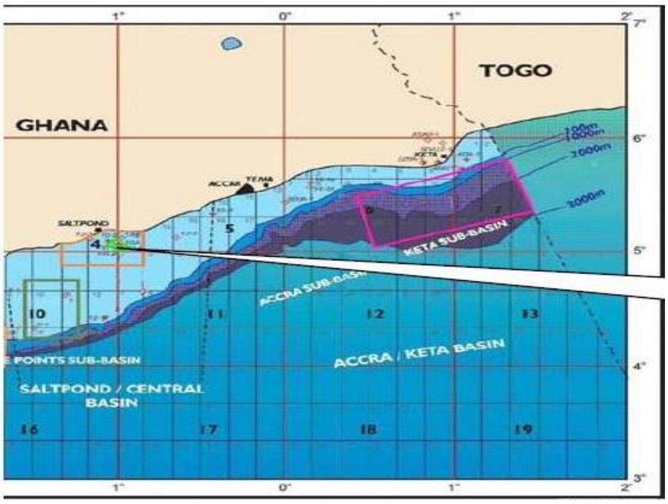

Fig 2. Saltpond offshore field

Methodology

The physical and chemical properties of the crude oil samples were determined following well established standard procedures: Density/specific gravity/API [12], pourpoint [13], total sulphur [8], salt in crude [14], total acid number [15], water by distillation [16], water and sediments [17] viscosity at 37.8 °C [27], reid vapour pressure at 37.8 °C [26] and the ash weight [25] were the parameters determined.

Results and Discussion

Physicochemical parameters of Saltpond and Jubilee crude oil

The Saltpond and Jubilee crude oils were analyzed for twelve physicochemical parameters. The results of the physicochemical parameters of both samples as shown in table 1, showed a perfect Pearson's correlation (r ≈1) which proves there is no significant difference between the physicochemical parameters of the two samples. Low water content in both crude oil samples (<1%) implies all measured physicochemical parameters are representatives of a "dry oil" [14]. Water can provide the beginning for microbial growth in crude oils. These very simple life forms live in the water and feed on the fuel at the water-fuel interface [10]. The low water content reduces the ability of such growth occurring. Any indication of microbial growth can be treated temporally by the addition of a "biocide" chemical additive to the fuel to kill the growth. The much preferred, long range solution would be to regularly drain the tank in order to eliminate the water, without which this growth cannot exist [10]. The low water content of the two crude oils also reduces its ability to serve as a collector of water soluble metals and salts present in the crude oil. This avoids fouling, deposits, corrosion at high temperatures and improves the quality of the crude oils. Generally, the two crude oils recorded low water and sediment contents (<1%). This is essential because it implies a low ash or particulate contamination of the fuel since both can contribute to increased deposits, corrosion or abrasive wear.

Table 1: Physicochemical parameters of Saltpond and Jubilee crude oil

Physicochemical Parameters	Saltpond crude oil	Jubilee crude oil
Density at 15 °C (kg/m^3)	848.6	849.3
Specific gravity	0.8486	0.8493
Gravity (°API)	35.1	35
Pour point (°C)	-3	-3
Total Sulphur (%wt)	0.168	0.237
Salt in crude (ptb)	4.40	8.07
Viscosity at 37.8 °C (cSt)	6.48	6.53
Reid vapour pressure at 37.8 °C (kg/m^2)	0.14	0.18
Total acid number (mg KOH/g)	0.17	0.20
Ash weight (% wt)	0.023	0.016
Water and sediments (%V)	0.1	0.1
Water by distillation (%V)	< 0.05	0.05

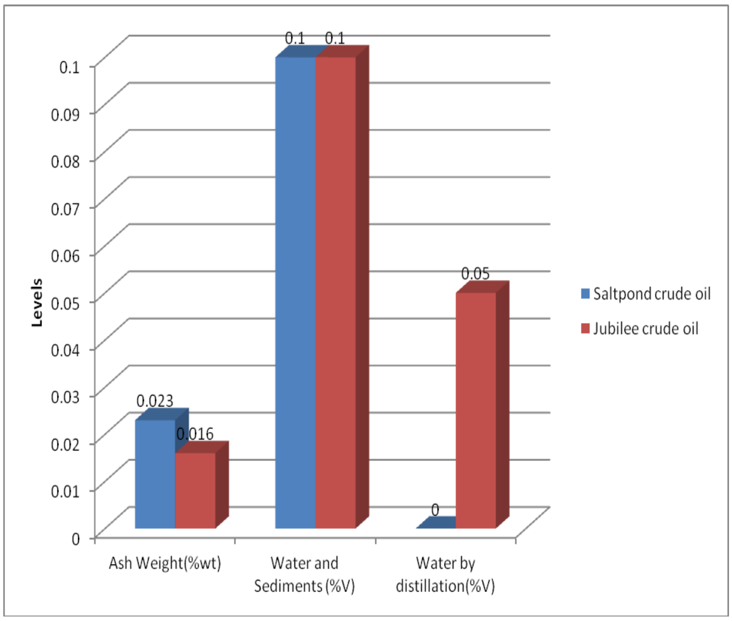

Fig 3: Comparison of Ash weight, Water and sediments and Water by distillation of Saltpond and Jubilee crude oil

The sediments level in crude oil has a correlation with the percentage ash weight and the trace element concentration. The higher the sediments level, the higher the percentage ash weight and the higher the concentration of metals in the ash. The lower water content of the Saltpond crude as shown in fig 3, revealed a higher sediment level which resulted in a higher percentage ash weight as compared to the Jubilee crude oil. Sediments in crude oil can be removed by settling, straining or filtration, or centrifuging in the shipboard fuel oil system. Usually, if sediment and water exceed one percent (1%), most oil suppliers would adjust bunkered fuel cost to compensate the buyer. As the specific gravity and the viscosity of fuel oils increase, the sediment level, which originates primarily from transport and storage contamination, will increase as a result of a slowing of the natural settlement process. As both the water and sediment content of fuel oil decrease, the usable energy in the fuel increases [10]. The percentage ash for the Jubilee and Saltpond crude oils were low (<0.1%). The ash content after combustion of a fuel oil takes into account solid foreign material (sand, rust, catalyst particles) and dispersed and dissolved inorganic materials, such as vanadium, nickel, iron, sodium, potassium or calcium. Ash deposits can cause localized overheating of metal surfaces to which they adhere and lead to the corrosion of the exhaust valves. Excessive ash may also result in abrasive wear of cylinder liners, piston rings, valve seats and injection pumps, and deposits which can clog fuel nozzles and injectors [10].

In heavy fuel oil, soluble and dispersed metal compounds cannot be removed by centrifuging. They can form hard deposits on piston crowns, cylinder heads around exhaust valves, valve faces and valve seats and in turbocharger gas sides. High temperature corrosion caused by the metallic ash content can be minimized by taking these engine design factors into consideration; hardened atomizers to minimize erosion and corrosion and reduction of valve seat temperatures by better cooling[10]. Table 2 compares some physicochemical parameters of the Saltpond and Jubilee crude to that from some other African counties.

Classification of Saltpond and Jubilee crude oils

Many different classifications can be applied to crude oil, depending on the different physical or chemical properties. API gravity ranges from 0-60°, where dense oils have low values and lighter oils have high values [19].

Generally, the dense oil is more viscous, less volatile and has high specific gravity and lower API gravity [20-22]. This observation shows clearly for the Saltpond and Jubilee crude oil in table 1.

Oil with less than 10 °API is denser than water and may be called extra-heavy oil or natural depending on viscosity. Heavy oils have gravities of less than 20°API, but more than 10°API. Medium crudes can be found between 20°API and 30°API. Light crudes have more than 30°API [19,23]. High API values of (35.1 and 35), coupled with low density (848.6kg/m^3 and 849.3 kg/m^3), specific gravity (0.8486 and 0.8493) and viscosity (6.58 cSt and 6.53 cSt) for Saltpond and Jubilee crude, respectively, signify that both samples are light crude oils. The price of a crude oil is usually based on its API gravity, with high gravity oils commanding higher prices.

An improvement in classification can be performed by including the content of various important pollutants, especially sulphur. The quality of many petroleum products is related to the amount of sulfur present [8].

The sourness of crude oil refers to the sulphur content. Crude oils with low sulphur content are commonly called sweet. The sulphur level in crude varies globally, from very low "sweet crude" (0.1 to 0.5) %wt to "sour crude" (around 1 to 3.3) %wt [9]. The total sulphur level obtained for Saltpond (0.168 ± 0.0210 %wt) and Jubilee crude oil (0.237 ± 0.015 %wt) using Sulphur-in-oil analyzer were low and within globally accepted range: (0.1-0.5) %wt for sweet crude oil [9]. Both crude oils can therefore be classified as light and sweet. Figs 4 and 5 compare the API and sulphur levels respectively of the Ghanaian crude oils to some crude oils from Nigeria.

Fig. 6 compares the sulphur levels of SaltpondS to Jubilee crude oil using Sulphur-in-crude analyzer to reported values from INAA measurements [11]. Both results were comparable and show a perfect Pearson's correlation (1).

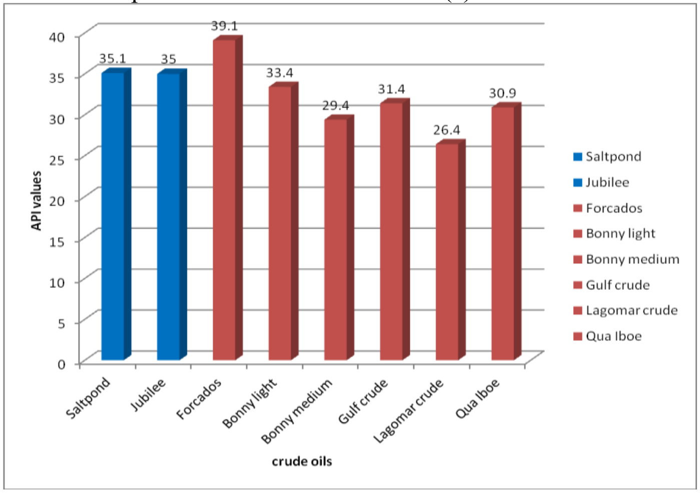

Fig 4: Comparison of API values of Ghanaian crude oils to that of some Nigerian crude oils [2]

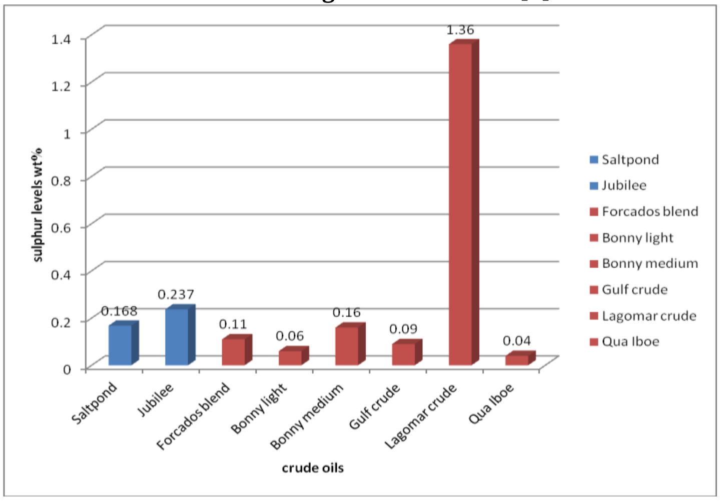

Fig 5: Sulphur levels of Ghanaian crude oils by sulphur-in-oil-analyzer compared to that of some Nigerian crude oils [2]

It is more complicated to refine heavy and sour crude oils, and consequently, they are worth less on the market compared to the light and sweet crude oils. Heavy crude needs more processing to yield high quality products due to their low API-gravity, high viscosity, high initial boiling point, high carbon residue and low hydrogen content. The most valuable oil is the light and sweet crude oil [19].

Combustion of high Sulphur containing crude oil generates dangerous levels of Sulphur dioxide (SO_2) with severe environmental and human health effects. SO_2 has respiratory impacts such as lung irritation, increased breathing rates, and suffocation. The most serious health effect is the aggravation of asthma and chronic bronchitis. Sulphur dioxides can also irritate the throat and eyes. It contributes to the formation of acid rain, which may cause extensive damage to materials and terrestrial ecosystems, aquatic ecosystems, and human populations [9]. Since the sulphur levels for both crude oils fall within acceptable limits, its environmental and human health effects will be significantly less compared to other crude oils reported with high sulphur content from countries, like Venezuela, Canada, Saudi Arabia, Kuwait, Iran, China and Libya as reported in [24,29].

Table 2: Some physicochemical parameters of Ghanaian crude oils compared to other African crude oils

Country	crude oil	Density at 15 °C (kg/m^3)	API°	Water & sediments(%V)	Salt in crude (mg/L)/Ptb
Ghana	Jubilee	849.3	35	0.1	8.07
	Saltpond	848.6	35.1	0.1	4.40
Congo[18]	Dzeno	892.9	26.9	0.3	22
	Congo composite	869.8	31.1	0.05	15
Gabon[18]	Mandji	879.8	29.2	0.05	25
Guinea[18]	Zafiro blend	871.8	30.8	0.24	15

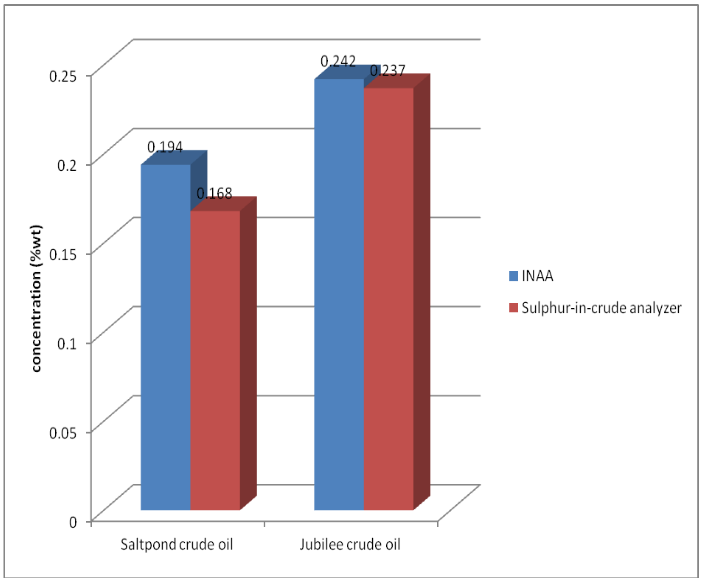

Fig 6. Sulphur levels in Saltpond and Jubilee crude by INAA [11] and Sulphur in crude analyzer

Conclusions

The Jubilee and Saltpond crude oils are light (API>30) and sweet (Sulphur levels < 0.5%wt) quality crude oils with low water content (<1%), coupled with low sediments level (<1%). This implies low or minimal microbial growth and reduced ability to serve as a collector of water soluble metals and salts. This enhances the quality of the crude oils as it is devoid of fouling and corrosion at high temperatures.

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