Effect of viscosity on the biodegradability of automotive lubricating oils

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Effect of viscosity on the biodegradability of automotive lubricating oils

O. O. Amund* and A. G. Adebisi*

Hydrocarbon-utilizing bacteria were isolated by enrichment from water samples collected from the Lagos lagoon and identified as species of Achromobacter, Acinetobacter, Alcaligenes, Arthrobacter, Bacillus, Flavobacterium, Micrococcus and Pseudomonas. The growth potentials of these isolates were evaluated using lubricating oils of different viscosities as substrates. All the organisms grew without lag on oils of low viscosity while they grew with pronounced lag phases on the highly viscous lubricating oil (bright stock). The biodeterioration potential of lubricating oils therefore appears to be closely related to their viscosities.

Keywords: viscosity, biodegradation, lubricating oils, bacteria

Introduction

The major source of lubricants is crude petroleum from which they are derived by vacuum distillation of a primary distillate with a boiling range above that of gas oil. They range from thin, easily flowing spindle oils to thick cylinder oils and are used in friction reduction between moving surfaces. Other functions include the removal of heat generated in lubricated equipment such as engine pistons, enclosed gears and machine tools while they also remove debris from the contact area and protect the lubricated or adjacent parts against corrosion by moisture.

The most important property of a lubricating oil which determines its suitability for various applications is its viscosity which is a measure of its internal friction and ability to flow. Various viscosity grades of lubricating oils are produced from the Nigerian crude ranging from the high viscosity residual oils or bright stocks prepared by propane de-asphaltalting and dewaxing of short residues to the low viscosity index distillate oils made from naphthenic lubricating oil distillates with low wax contents. The increase in the production capacity of the petroleum refining industry in Nigeria has made the biodeterioration of petroleum products in bulk storage an important consideration. Whilst a number of reports have appeared on microbial activity within in-use lubricating oils, the storability of these products has received little research attention. This paper therefore reports the relative ease of microbial degradation of three types of lubricating oil produced from the Nigerian crude in relation to their viscosities.

Materials and methods

Three grades of lubricating oil samples designated as 150 Neutral (150 N), 500 Neutral (500 N) and Bright stock were obtained from the lubricating oil plant of Mobil (Nigeria) Limited, Apapa, Lagos. The samples were sterilized by autoclaving at 121°C.

Hydrocarbon-utilizing bacteria were isolated from water samples collected from the Lagos lagoon by enrichment using the mineral salts medium of Mills et al. in 250 ml conical flasks. The medium had the following composition: NaCl, 10.0 g; MgSO4.7H2O, 0.42 g; KCl, 0.29 g; KH2PO4, 0.83 g; Na2HPO4, 1.25 g; NaNO3, 0.42 g; deionized water, 1.0 l; pH 7.2, while a multigrade motor oil (SAE 40) was used as the sole carbon source. The cultures were incubated with shaking at 120 rev/min and 28°C for seven days. Pure cultures were isolated by plating out serial dilutions of the enrichment broth on nutrient agar plates to obtain distinct bacterial colonies. Each isolate was tested for ability to utilize lubricating oils, crude oil (Forcadex blend), n-alkanes, aromatic hydrocarbons, sodium acetate and sodium succinate in the mineral salts medium. The oil-degrading bacteria were maintained on nutrient agar slants at 4°C and were identified in accordance with the identification schemes of Cowan.

A Ubbelohde viscometer was used for viscosity determination. The oil samples (100 ml) were made to run in the viscometer and the time in seconds was noted at the collection of 60 ml of each oil in a flat-bottomed flask. The kinematic viscosity was determined by the ASTM correlative method. The specific gravity of the oils was determined by the use of hydrometers.

Overnight broth cultures of each isolate (1.0 ml) were seeded into a mineral salts medium containing each of the oils (0.5% v/v) as carbon source in 250 ml conical flasks and incubation with shaking followed (120 rev/min) at 30°C. The optical density (OD) at 600 nm, total viable counts (tvc), pH of the culture medium and the residual oil were monitored at the intervals already described.

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Results and discussion

The lubricant base oils used in this study were found to vary in their viscosities and specific gravities. The viscosities were 0.41, 1.58 and 8.05 centistokes (cSt) for 150 Neutral, 500 Neutral and Bright stock respectively while their specific gravities were found to be 0.84, 0.86 and 0.89 respectively.

The enrichment of water samples from the Lagos lagoon using the automotive lubricating oil (SAE 40) as carbon source resulted in the isolation of eleven bacterial strains which were subsequently identified as species of Achromobacter, Acinetobacter, Alcaligenes, Arthrobacter, Bacillus, Flavobacterium, Micrococcus and Pseudomonas. Substrate specificity tests showed that the organisms grew on long-chain n-alkanes, including n-tetradecane and n-hexadecane. However, the aromatic substrates such as naphthalene, anthracene and phenanthrene were not utilized.

The results of biodegradation and growth experiments are shown in Table 1 and Fig 1. Growth of the test organisms on the lubricating oils resulted in a gradual decrease in the pH of the culture medium due to the production of acidic metabolites. Each of the organisms exhibited similar growth rates and generation times on the three test oil samples. However, all the organisms exhibited pronounced lag phases lasting for 2–6 days on the highly viscous Bright stock oil while they grew without lag on the lighter oils (150 N and 500 N) as illustrated in Fig 1. In addition, all the organisms utilized 70–80% of the oil substrates within 21 days of incubation.

The behavioural pattern of hydrocarbon-utilizing bacteria on oils of different viscosities presents an interesting observation. The physical state of petroleum hydrocarbons is known to have a marked effect on their biodegradation. Hydrocarbon-degrading microorganisms act mainly at the oil-water interface and have been microscopically observed growing over the entire surface of an oil droplet. Availability of increased surface area should therefore accelerate biodegradation. The degree of spreading is also known to determine in part the surface area of oil available for microbial colonization by hydrocarbon degraders which in turn is proportionately dependent on the degree of viscosity of the oil. The dispersion potential of oils in the aqueous medium therefore decreases with an increase in viscosity. From the point of view of microbial hydrocarbon degradation, dissolution and emulsification of hydrocarbons appear to have a positive effect on degradation rates. This underscores the use of dispersants in the breaking up of oil spills at sea.

It is evident from the results of this investigation that the Bright stock lubricating oil was less readily attacked by the microbial strains tested due to its high viscosity, and with an apparent implication that lighter oils deteriorate faster than highly viscous ones in storage. This also explains the reason why the lubricating oil in service is more prone to biodeterioration than unused oil as previously reported in literature.

References


Table 1 Growth potentials of hydrocarbon-utilizing bacteria on automotive lubricating oils

<table>
<thead>
<tr>
<th>Bacterial strains</th>
<th>Specific growth rate, ( u )</th>
<th>Generation time, ( d )</th>
<th>Lag phase, ( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150 N</td>
<td>500 N</td>
<td>Bright stock</td>
</tr>
<tr>
<td>Acinetobacter calcoaceticus</td>
<td>1.27</td>
<td>1.32</td>
<td>1.32</td>
</tr>
<tr>
<td>Pseudomonas stutzeri</td>
<td>1.17</td>
<td>0.97</td>
<td>1.33</td>
</tr>
<tr>
<td>Achromobacter sp.</td>
<td>1.46</td>
<td>1.32</td>
<td>1.23</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>1.14</td>
<td>1.28</td>
<td>1.40</td>
</tr>
<tr>
<td>Arthrobacter sp.</td>
<td>1.19</td>
<td>1.17</td>
<td>1.12</td>
</tr>
<tr>
<td>Micrococcus sp.</td>
<td>1.15</td>
<td>1.75</td>
<td>1.04</td>
</tr>
<tr>
<td>Flavobacterium sp.</td>
<td>1.23</td>
<td>1.58</td>
<td>1.12</td>
</tr>
<tr>
<td>Bacillus sp.</td>
<td>1.20</td>
<td>1.11</td>
<td>1.37</td>
</tr>
<tr>
<td>Alcaligenes sp.</td>
<td>1.32</td>
<td>1.32</td>
<td>1.15</td>
</tr>
<tr>
<td>Pseudomonas fluorescens</td>
<td>1.02</td>
<td>1.17</td>
<td>1.10</td>
</tr>
<tr>
<td>Flavobacterium sp.</td>
<td>0.90</td>
<td>1.10</td>
<td>1.29</td>
</tr>
</tbody>
</table>
Fig 1 Growth profiles of Acinetobacter calcoaceticus and Bacillus sp. on lubricating oils. (A): Acinetobacter calcoaceticus; (B) Bacillus sp.; ○, total viable counts (TVC); ●, optical density (OD600); △, residual oil (%); Δ, pH