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Assessment of chemical content of base oil blends used as alternative diesel fuel for environmental safety

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ABSTRACT

Increases in crude oil prices have led the transportation sector drivers to seek alternative cheaper fuels for diesel engines. A blend of virgin and/or non-standard base oils with diesel fuel called Number 10 lube (NTL) has been widely used for such purposes in public buses or trucks all over Turkey. This study was conducted as a first step to assess the occurrence, spatial distribution, and potential sources of Ag, As, Ba, Bi, Cd, Cl, Co, Cr, Fe, Li, Mn, Mo, Ni, Pb, Rb, Se, Sr, Tl, V, and Zn in this generic oil to make further evaluation of environmental and public health. A microwave-assisted combustion procedure was applied for the determination of metals and metalloids in NTL samples by inductively coupled plasma-mass spectrometry while a field test method was used for Cl. The range of total metallic/metalloid elements and chlorine concentration was between 0.04 and 189 μg/g, and from below detection to 825 μg/g, respectively. Unexpectedly, samples varied in types and levels of constituents between the western and eastern parts of the country. The enrichment of Zn, Mo, and Cl in NTL samples suggests that some sort of waste oils, lubricating oils, chlorinated solvents, or transformer oils were mixed with base oils. The metal emission rates derived from the annual consumption of NTLs were far beyond the estimations for diesel vehicles and industrial sources. Therefore, the problem, which leads to financial, environmental, and health concerns in Turkey, could probably be experienced in other countries and, thus, should be managed properly.

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Introduction

Crude oil is a vital raw material with a wide variety of uses in industrial and domestic applications. Considering the impact of the dynamics of crude oil and refining product prices for oil-importer countries, the petroleum industry plays a decisive role in the performance of many sectors including transportation. As emphasized by Rodrigue and Notteboom (2013), the transportation sector may experience a setback during periods of recession. In such periods, sectors or fleet operators that are primarily impacted by high fuel prices or the recession may come up with their own solutions to overcome the situation, depending on the country's level of development. Despite international efforts, such as the World Environment Conference held in Kyoto in 1997 confirming the necessity to reduce petroleum wastes in the environment, Number 10 lubes (NTLs) were a key solution for the enormous increase in world oil prices experienced in Turkey after 2004. Accordingly, medium- to heavy-duty truck or bus drivers have preferred different fuel alternatives for diesel engines. There have been three basic uses: blending virgin/non-standard base oils with diesel fuel, fuelling them directly as diesel substitutes, or

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mixing them with waste oils. This issue emerged in the early 2008 in Turkey due to a higher tax rate on diesel fuel compared with that on lubricants. Since then, the use of NTLs as an alternative fuel has increased and has become widely distributed all over the country, leading to potential problems for the economy and environmental quality.

According to Turkish Statistical Institute data (TSI, 2013), the total number of vehicles registered progressively increased between 2004 (10,236,357) and 2012 (17,033,413) in Turkey. The consumption of petroleum and other liquid fuels, on the other hand, has increased at a relatively slower rate and even remained stable especially in 2009 and 2010 in the country (UPEI, 2011). This situation could be attributed to the potential use of base oil and/or a mixture of different oil types, i.e., NTL, in lieu of diesel fuel (TPIA, 2012b). As can be seen in Fig. 1, the temporal trends indicates almost a plateau for base oil demand (ca. 500,000 tones/year) compared to rising supply parallel to movement in crude oil prices especially after 2008. This excess supply is compensated by the buses and trucks used in public transportation and intercity traffic. As of 2013, the NTL sector volume is considered to reach over 1 million tons while the amount was around 10–15 thousand tones/year in the early years (TPIA, 2008b). Considering the special consumption tax on diesel fuel compared to base or mineral oil (difference is around 0.65 $/L) in Turkey, NTL used as an alternative fuel in diesel engines has resulted in a tax loss exceeding $3 billion between 2008 and 2012 (TPIA, 2012a). Such common usage would also bring about accidents and loss of lives (TPIA, 2012a) due to unsuitable characteristics of NTL like low flash point (<55 °C) causing explosions in public buses (TPIA, 2012b).

There has not been much information reporting the use of non-standard fuels in diesel engines (Arpa et al., 2010; Beer et al., 2000; Caterpillar, 1996; Dong et al., 2012; Naima and Liazid, 2013). The fleet operators in the transportation sector blend diesel with up to 7% waste crankcase oil due to the financial benefits of this practice (Beer et al., 2000). In non-transport sectors, blending used engine oil with diesel fuel for use in heavy duty diesel engines is suggested without severe engine problems (Caterpillar, 1996). While Arpa et al. (2010) observed no problem in terms of diesel engine performance using diesel-like fuel produced from waste engine lubrication oil, they found higher HC, CO, NO_x, and SO_2 compared to diesel fuel in the exhaust emissions. On the other hand, according to these authors' knowledge, the use of base oils directly or after blending with waste oils for such purposes is uncommon (Wojtyniak and Kowalewicz, 2005). Number 10 lube is the name given to lubrication-grade base oils (TPIA, 2008a). Major constituent of NTLs is group-I-type base oils, namely SN100 (90–100%), plus SN150 and SN500 with minor percentages (2–10%) in the formulations (Akkapili, 2012). However, in the market, NTLs including waste lubricating oil, transformer oil, solvent, used cooking oil, and illegal fuel were also sold as diesel fuel. Therefore, constituents and properties of fuel are of great importance in terms of the pollutants they emit into the atmosphere. The pollutants emitted from the exhaust in the form of gases or particles pose a threat to the environment and human health considering contaminants, including heavy metals, polyaromatic hydrocarbons, polychlorinated biphenyls, halogens, and phenols, present in waste oils (Anderson et al., 2003; Marnane, 2012; Vazquez-Duhalt, 1989; Winther and Slento, 2010) depending on their specific use.

A written question seeking detailed information on the topic of concern was submitted to the Turkish Grand National Assembly (TGNA, 2011). The state of the scientific knowledge in the answers to this question was limited and this further increases the importance of this study. In the light of the information summarized for the aforementioned issue, the identification of the environmental impacts of such situations requires a narrower approach. In this context, a preliminary investigation was carried out to assess the occurrence and spatial distribution of metallic/metalloid elements and halogen levels in NTLs commercially traded as diesel fuel. The results are discussed in the context of base oil/diesel/waste oil

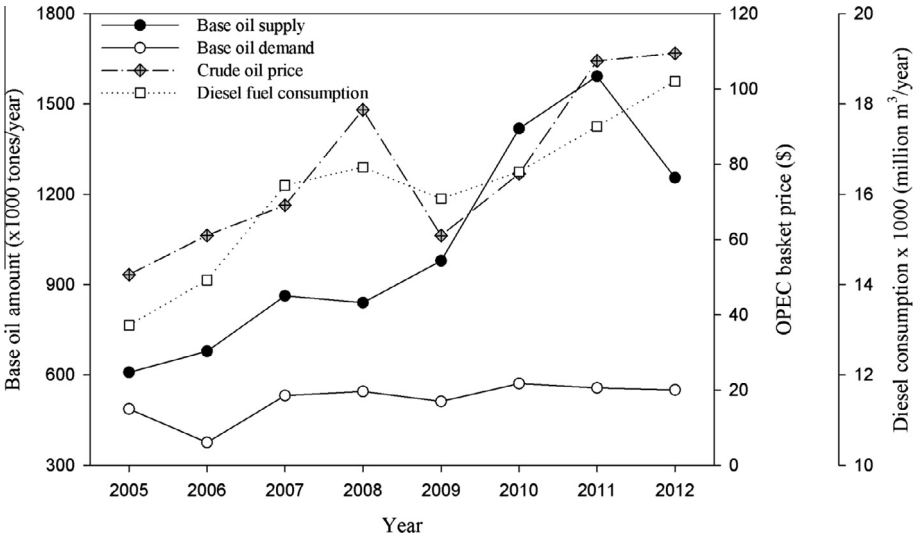

Fig. 1. Crude oil prices (OPEC, 2013) and base oil supply–demand data in Turkey (TPIA, 2012b).

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