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STUDY OF POST-RADIATION EFFECTS IN DIESEL FUEL

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Abstract: The study investigates the change of physico-chemical and operational properties of diesel fuel through the addition of a little toluene under Co^{60} ionizing radiation. A mixture of toluene and diesel fuel was subjected to irradiation at a dose rate of P = 0.07 Gy/h, with absorbed dose ranges D = (24–90) kGy, and a 1% (vol) toluene concentration. The study evaluates the density and viscosity of diesel fuel before and after irradiation at various absorbed doses. The selection of a radiation-resistant diesel fuel is achievable by identifying an appropriate antirad.

Keywords: diesel fuel, radiolysis, radiation resistance, toluene.

1. Introduction

When exposed to ionizing radiation, organic substances undergo complex radiation-chemical transformations. Thus, beyond considering well-known physico-chemical properties of organic fuels and lubricants, it becomes essential to assess their ability to function under radiation conditions, that is, their radiation resistance. The speed and direction of the polymerization processes that occur under the influence of radiation depend on factors, such as the density of olefin in the irradiated system, temperature of the medium, radiation dose, and dose rate [1-3]. The effect of radioactive radiation is mainly reduced to ionization of the energy-absorbing medium and induction of free radicals depending on the concentration of radical chain and ionic processes. Under this condition, as a result of cracking, dehydrogenation, isomerization, and polymerization of hydrocarbon fuels, they are formed simultaneously with fissile low-molecular compounds as a product of radical and ion recombination.

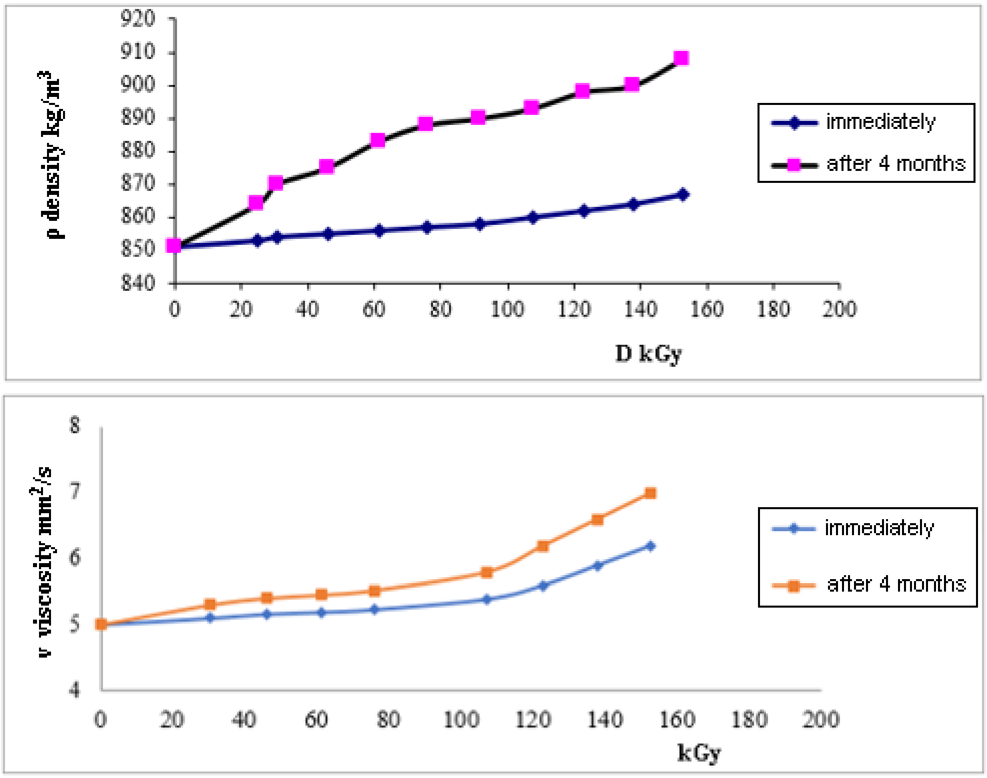
According to the fractional composition in diesel fuel (DF), the completeness of combustion in cylinders, smoke levels, and exhaust gas toxicity are determined. The fundamental physical and chemical properties of the fuel are contingent on its density. It is possible to enhance the resistance to the effects of gamma rays by adding a small quantity of aromatic compounds to diesel fuel, which increases the radiation resistance of diesel fuel. During the first 10^{-14} seconds of exposure of fuels to ionizing radiation, the initial radiation-chemical processes result in the formation of ions and excited molecules, leading to dissociation and the breaking of chemical bonds with the formation of free radicals. At the same time, the structuring and decomposition of organic compounds take place. The stability of fuel components' chemical composition under operating conditions, including high temperatures and radiation, holds significant practical importance. Investigating the impact of radiation on the overall fuel composition, defining requirements for the fuel composition, and understanding its resistance to radiation are crucial research tasks.

Typically, effective antioxidant, anti-corrosive, detergent, and neutralizing additives in diesel fuel, help mitigate the detrimental effects of sulfur compounds, leading to increased engine service life, reduced fuel consumption, decreased wear and tear, and minimized carbon deposits. Aromatic compounds, such as benzene, toluene, phenylenediamine, phenylnaphthylamines, etc. are common antirads. The amount of aromatic antirads in fuels is usually 0.1-10%. Aromatic hydrocarbons exhibit resilience to high temperatures and radiolysis, prompting detailed studies to explore their potential, as antiradiation agents. The presented work aims to investigate changes in the operational characteristics of diesel fuel with the addition of a small amount of toluene under the influence of ionizing radiation.

2. Methodology

Diesel fuel (DF) samples, enclosed in ampoules and sealed in vacuum, underwent irradiation at room temperature using an MPX γ-30 type Co^{60} gamma source within the absorbed dose range of D=(15-150) kGy. Additionally, a mixture of toluene with diesel fuel (+DF) at toluene concentrations of 1,3, and 5% were exposed to a dose of P=0.07 Gy/h within the absorbed dose range of D=(24-90) kGy. DF density and viscosity were assessed before and after irradiation at various absorbed doses. Viscosity measurements were conducted in VPZh-2 type viscometers in accordance with DÜIST 33-66, while densities were measured using a pycnometer in accordance with DÜIST 3900-85.

3. Experimental part

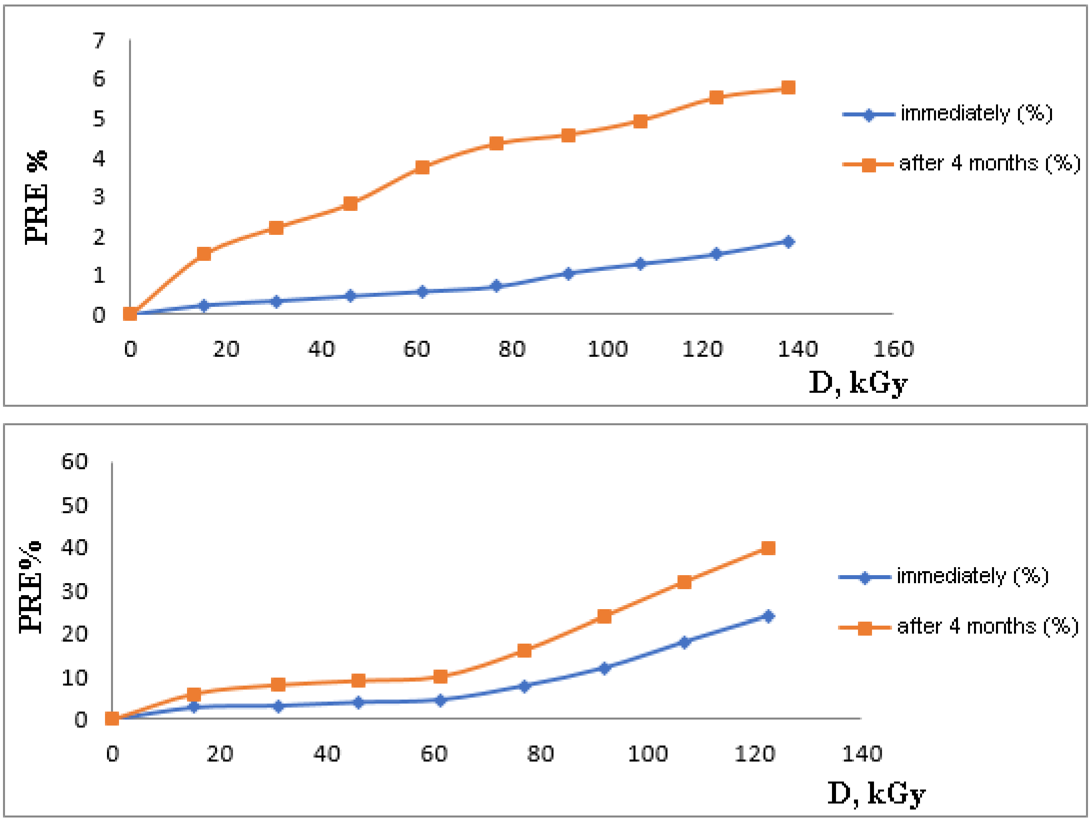


a

b

Fig. 1(a, b). Effects of gamma radiation on initial properties of diesel fuel immediately and after 4 months (P=0.072 Gy/h).

As evident from Figure 1 (a, b), the viscosity and density of fuels increase with the rise in absorbed dose. Post-irradiation, the kinetics of post-polymerization processes reveal that the process speed and its contribution to total polymerization depend on irradiation time, initial mixture density, and dose. Fuel oxidation is a complex, multistep process resulting in free radical formation, consequently, resinous substances accumulate during radiation polymerization and condensation of oxidation products, leading to deposits. This leads to the formation of deposits in the valves and combustion chambers, spark plugs.

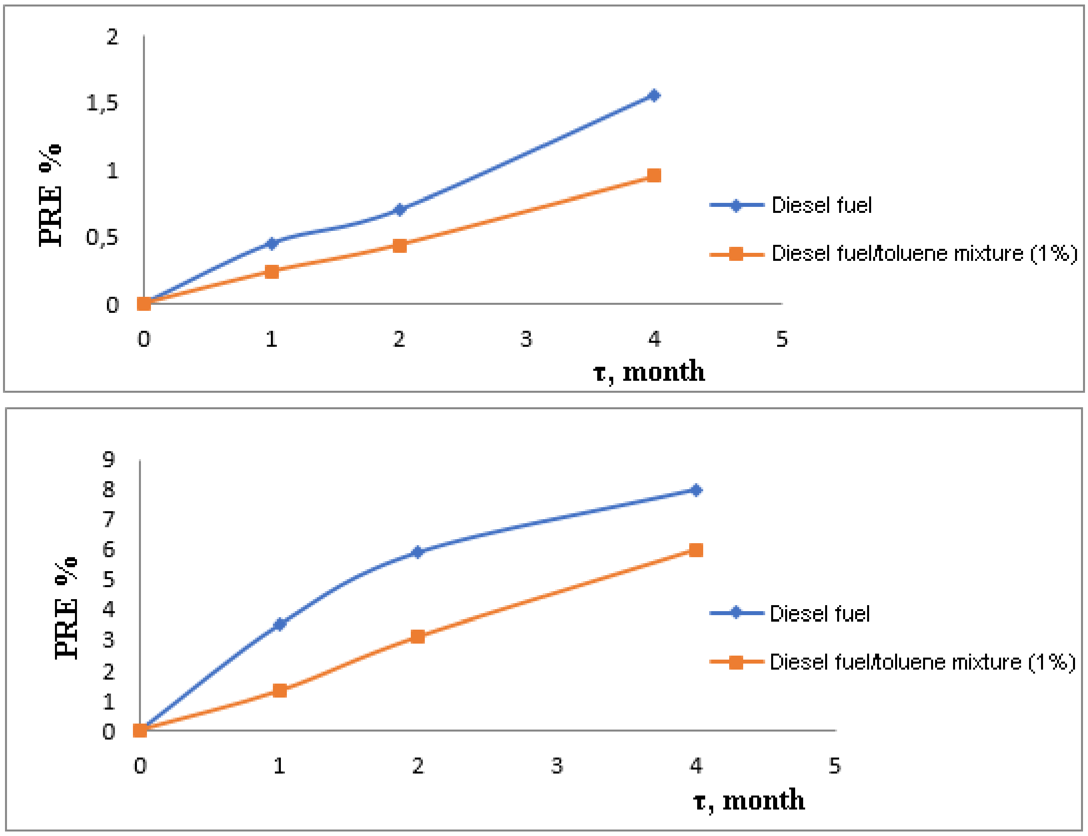


a

b

Fig. 2(a, b). Dependence of diesel fuel density (a) and viscosity (b) on the absorbed dose immediately and 4 months after the radiation effect. (P=0.072 Gy/h).

Finding the optimal concentration of toluene in the diesel fuel composition is essential to maintain constant viscosity and density irrespective of the absorbed dose. The impact of absorbed radiation dose on the density, viscosity, and molecular structure of the initial diesel fuel mixed with 1/99% toluene/diesel fuel was investigated. Antirads, when mixed with hydrocarbons, shield them from radiation effects. Figure 3(a, b) illustrates the immediate effect of gamma irradiation on the density and viscosity of a toluene-diesel mixture at 1% (tot.) concentration.



a

b

Fig. 3(a, b). Dependence of the post-radiation effect of density (a) and viscosity (b) of DF and DF/1%toluene mixture on time (month). D=72 kGy.

The post-radiation effect exhibits an unstable course from the initiation of the reaction to its complete cessation (breaking of the kinetic chain). Studying the kinetics of post-polymerization effects immediately after irradiation and some time after irradiation reveals that the process speed and its contribution to total polymerization depend on irradiation time, initial mixture density, and dose. The addition of antirads allows for the determination of a more radiation-resistant composition of DF. The radiation resistance of aromatic compounds stems from their relatively low initial excitation energy. Part of the energy absorbed by the aliphatic part of the molecule can be transferred to the aromatic part. This energy is transmitted along the aromatic ring. To increase the radiation resistance of diesel fuel, toluene is added to the composition at an anti-radiation concentration of 1%, resulting in viscosity and density with increasing absorbed dose.

The subsequent figures (Figures 4-6) illustrate the concentrations of specific components of diesel fuel immediately after gamma irradiation and after 2 months.

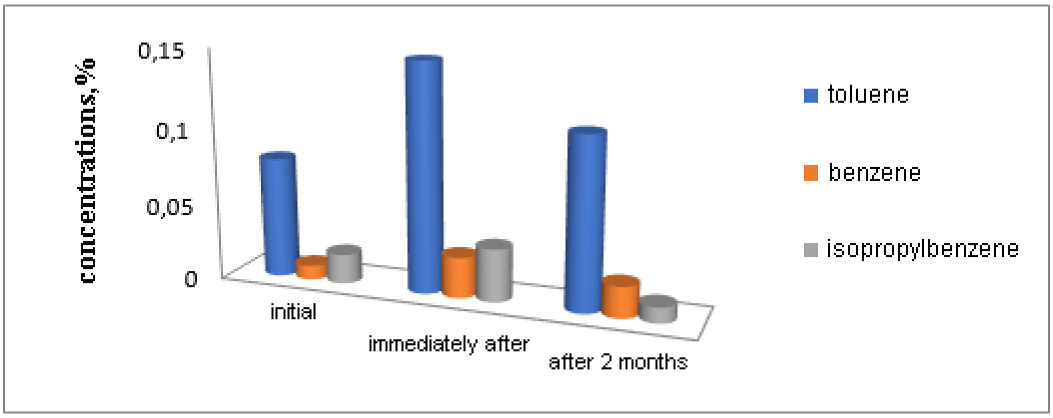


Fig. 4. Concentrations of toluene, benzene, and isopropylbenzene in diesel fuel, immediately after and 2 months after gamma irradiation (%).

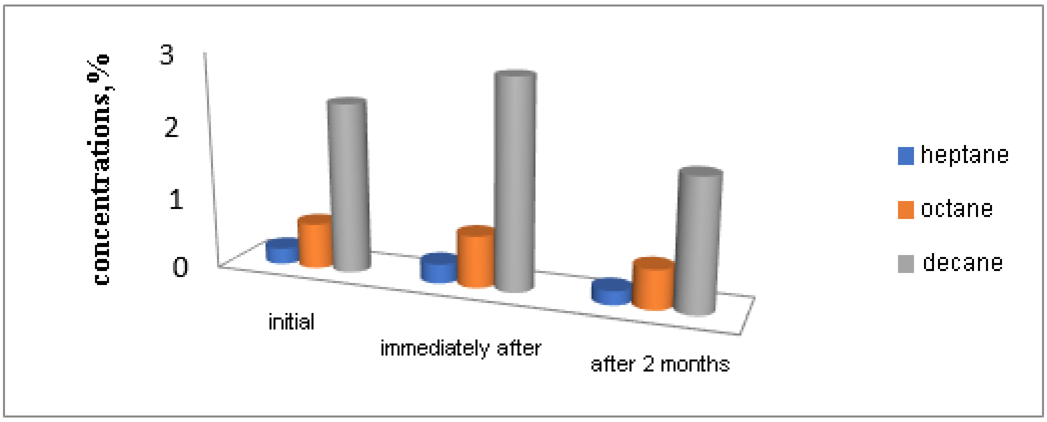


Fig. 5. Concentrations of heptane, octane, and decane in diesel fuel, immediately after and 2 months after gamma irradiation (%).

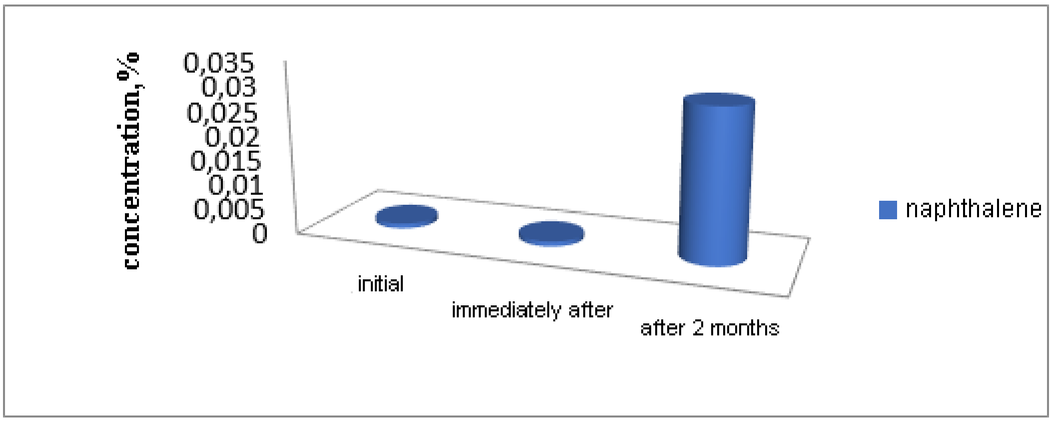


Fig. 6. Concentration of naphthalene in diesel fuel immediately after and 2 months after gamma irradiation (%).

4. Conclusion

Diesel fuel (DF) samples, enclosed in ampoules and sealed in a vacuum, underwent irradiation at room temperature using an MPX γ-30 type Co^{60} gamma source within the absorbed dose range of D=(15-150) kGy. Additionally, a mixture of toluene with diesel fuel (+DF) at toluene concentrations of 1, 3, and 5% was exposed to a dose of P=0.07 Gy/h within the absorbed dose range of D=(24-90) kGy. It was observed that as the absorbed dose increased, the viscosity and density of the fuel also increased, negatively impacting the technical properties of DF. High viscosity led to higher smoke emissions, and increased fuel consumption during fuel combustion, reduced engine efficiency, disrupted the combustion process, elevated incomplete combustion products, and caused soot formation. Higher density resulted in an increased rate of wear and tear and thermal stress on spare parts. The radiation resistance of aromatic compounds arises from their relatively low initial excitation energy. Part of the energy absorbed by the aliphatic part of the molecule can be transferred to the aromatic part. This energy is transmitted along the aromatic ring. In studies, to enhance the radiation resistance of diesel fuel, toluene was added to the composition at concentrations of 1, 3, and 5%. Notably, at an optimal toluene concentration of 1% in DF, viscosity and density exhibit minimal changes with an increase in absorbed dose. The addition of antirads allows for the determination of a more radiation-resistant composition of DF. Examination of the kinetics of post-polymerization effects immediately after irradiation and some time after irradiation reveals that the processing speed and its contribution to total polymerization depend on irradiation time, initial mixture density, and dose.

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ИССЛЕДОВАНИЕ ПОСТРАДИАЦИОННЫХ ЭФФЕКТОВ В ДИЗЕЛЬНОМ ТОПЛИВЕ

Л.Ю. Джаббарова, И.И. Мустафаев, А.С. Мирзаева

Резюме: Целью представленной работы является изучение изменения физико-химических и эксплуатационных свойств дизельного топлива при добавлении небольшого количества толуола под воздействием ионизирующего излучения Co^{60}. Смесь толуола и дизельного топлива облучалась при мощности дозы P = 0,07 Гр/с, диапазон поглощенных доз D = (24–90) кГр, концентрация толуола 1 % (об.). Определены плотность и вязкость дизельного топлива до и после облучения различными поглощенными дозами. Выбрать радиационно-стойкое дизельное топливо можно, подобрав подходящий антирад.

Ключевые слова: дизельное топливо, радиолиз, радиационная стойкость, толуол.

DİZEL YANACAĞINDA POST-RADİASİYA EFFEKTLƏRİNİN TƏDQİQİ

L.Y. Cabbarova, İ.İ. Mustafayev, A.S. Mirzəyeva

Xülasə: Təqdim olunan işin məqsədi Co^{60} ionlaşdırıcı şüalanmanın təsiri altında azacıq toluol əlavə etməklə dizel yanacağının fiziki-kimyəvi və istismar xassələrinin dəyişməsini öyrənməkdir. Toluolun dizel yanacağı ilə qarışığı P = 0,07 Gy/s doza sürətində, udulmuş doza diapazonlarında D = (24-90) kGy, 1% (həcm) toluol konsentrasiyasında şüalanmışdır. Müxtəlif udulmuş dozalarda şüalanmadan əvvəl və sonra dizel yanacağının sıxlığı, özlülüyü müəyyən edilir. Uyğun antirad seçməklə radiasiyaya davamlı dizel yanacağı seçmək olar.

Açar sözlər: dizel yanacağı, radioliz, radiasiya davamlılığı, toluol.