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Biodiesel engine fuel for internal combustion engine and its particulate matter emission on health: A Review

Mohd Muzammil Zubair [*1,2], Mohamed Ahmed Alawad Abdallah [2]

[1]Center for Advanced Material, Qatar University, Doha, Qatar
[2]Department of Mechanical and Industrial Engineering, Qatar University, Doha, Qatar
*Corresponding Authors Email: mz2103516@qu.edu.qa

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Abstract: Diesel engine are one of the most widely employed unit for power generation and it alone consumes large amount of entire petroleum. On the other hand, it is the major contributor of particulate matter (PM) emission into the outdoor environment. Particulate matter (PM) is the amalgamation of different particle with liquid droplets and can be generated directly from the source or can be formed through the atmospheric chemistry. Particulate matter (PM) generation is harmful for human health in numerous ways discussed in this paper. There is no threshold limit for particulate matter (PM) exposure for human being. However different organizations such as US EPA and ASHRAE have set limits for acceptable concentration of particulate matter (PM) exposure. The paper has gone through the effects of different types of biodiesel fuel from the literature on quantity of particulate matter (PM). It was found that both the existence of high concentration of the Oxegentaed atoms and the robust dual bonds between it and the Carbon in the biodiesel creates less percentage of soot, giving lower PM emissions amount for the biofuel combustion. However, rising the length of fatty acid chain impacts remarkable growth in microscopic particle mode and there is a growth in the number of microscopic particles, which is a real crisis for running engines with biofuels due to the smaller particles sized being more dangerous to human health.

Keywords: Biodiesel; engine; fuel; particulate matter; emission

1. Introduction

The need of the consumption of fossil fuels is continuously rising from the 18th century industrial revolution and because of the rapid population growth, advancement in transportation industry, and other energy sectors gives new high to this trend. When it comes to the consumption of fossil fuel in transportation sector, Internal combustion engine is the name that come into the mind of all. Internal combustion engine is sometimes called the heart of the transportation vehicle. Internal combustion engine can be classified on the basis of application, no of strokes, fuel used and method of ignition. Any internal combustion engine is called Diesel engine in which diesel fuel fed into the engine cylinder, inside the cylinder air is compressed enough to the required temperature to ignite the diesel fuel and convert its chemical energy into the mechanical energy. Application of diesel engine is in variety of applications such as electricity generation, automobiles, power plants etc. [1]. Diesel engine finds its major use in machines such as diesel cars, trucks, locomotives, ships, farm and construction equipment's. Diesel is the working fuel for diesel engine, and it emits pollutants such as Particulate matter (PM), soot, NOx, hydrocarbon (HC), carbon monoxide (CO), and other harmful pollutants [2]. From all pollutants in the outdoor environment, PM is the most dangerous for human health[3]. Exposure of PM into the air leads to air pollutants which elicits different diseases and symptoms such as lungs disease, vascular disfunction and heart diseases. The size of the particulate matter (PM) plays a major contribution in affecting human health. The larger size particle PM10 remain in air for less period of time and if accidently inhaled by any human being, get trapped in the trachea and comes out of the body through sneezing or coughing.

While particulate matter (PM) which are smaller in size than 2.5μm remain in the air for longer period of time and its chances are more of being inhaled. If so they travel deeper into the lungs and gets into the blood through alveoli.

2. Background of particulate matter

Particulate matter is a combination of different solid and liquid particles that can be organic or inorganic depending on their chemical composition. The chemical components of PM have been shown to be varied enough to include sulfates, nitrates, endotoxins, cell fragments, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and some of the metals like nickel, zinc, iron, nickel, copper, and vanadium [4]–[6]. Primary pollutant sources can either emit PM directly into the environment or emits secondary pollutants including sulphur dioxide, nitrogen dioxide, and volatile organic compounds, which can be converted into PM through atmospheric chemistry [7].

Due to the size of the particle, particulate matter (PM) is further categorized into distinct groups. coarse (PM10, diameter <10μm), (b) fine (PM2.5, diameter <2.5μm), and (c) ultrafine particle, UFP (PM0.1, diameter <0.1μm) shown in fig. 2 [8], [9]. The propensity for particles to cause health concerns has been directly connected to their size. Coarse particles (PM10) arise from several natural and man-made sources [10] and if accidentally inhaled through the nose do not penetrate beyond the upper airway system [11]–[13], PM2.5 on the other hand, can pass through the deeper sections of the lungs and mix with the blood circulation through the alveoli [11]. The combustion of fossil fuels generates fine and ultrafine particles (UFP) and represents a greater threat to human health by remaining in the lungs for a longer period [14]. For particle with 30μm size, gravity causes an almost instantaneous deposition of particles, smaller particles remain suspended for long times and can travel far from the source of origin, remaining in the air for a long period of time. PM10 particle exhibits a short lifetime and travels a small distance (inferior to 10km). On the opposite fine particle (PM2.5) can last days or weeks and travel up to 10^6 km. The concentration of PM2.5 outdoor varies greatly with time and location [15].

3. Impacts of PM on human exposure

Due to the significant exposure risk even at low concentrations of PM in the air, it has been a source of worry that air pollution caused by PM might have a negative effect on human health [16]. Particulate matter in the atmosphere has the potential to transport a wide range of pathogenic components, including heavy metals, viruses, germs, and polycyclic aromatic hydrocarbons (PAHs), all of which have the potential to have a negative impact on human health. When fine particle pollution is breathed into the body, it travels through the respiratory tract and eventually reaches the pulmonary alveoli, where it triggers an inflammatory reaction and inhibits the immune system's ability to mount a defense [17]. Once it has reached the lungs, PM has the potential to enter the circulation and then go on to other organs. PM may disrupt normal cellular physiological processes by inducing oxidative stress, vascular inflammation, genotoxicity, platelet activation, and other mechanisms. This may result in tissue and organ damage, and it may also facilitate the occurrence and development of lung diseases, cardiovascular diseases, and other diseases [18]. The pathophysiological pathways that will be detailed here have been associated to PM, which has been linked to a variety of health outcomes that are not positive.

Lung disease

Due to the fact that the lung is the major location of PM deposition, it is one of the key organs that PM may cause damage to. Multiple research [18] have shown a correlation between PM and inflammation of the airways. Following inhalation and subsequent deposition on the surface of pulmonary bronchioli and alveoli, particulate matter (PM) is subsequently taken up by lung cells such as epithelial cells and alveolar macrophages. As a consequence of this, PM induces oxidative stress in these cells and causes additional dysfunctions that disrupt their normally efficient operation. Exposure to PM would be the culprit in the development of chronic bronchitis, COPD, and asthma, as well as their ongoing maintenance.

Diabetes

According to the findings of a meta-analysis of prospective trials that included more than 2 million participants, the relative risk of developing type 2 diabetes mellitus increased by 39% for every 10 mg/m^3 increase in PM concentrations. A meta-analysis of 13 separate clinical tests carried out in either Europe or North America came to the same conclusions. [19].

Cardiovascular disease

In a meta-analysis of 35 studies, rates of heart failure hospitalization or death increased by 2% per 10mg/m3 in PM concentrations, with strongest associations seen on the day of exposure. It was estimated that a mean reduction in PM of 3.9mg/m3 would prevent 7978 heart failure hospitalizations [20]. PM can also trigger pathophysiological responses that increase blood pressure and result in the development of hypertension [21,22].

4. Fuel Types:

Biofuels are coming from a treated biomass, the term assigned to the biologic textile in animal populations or plants or an ecosystem. it can be described as a source of renewable energy where the animals and the plants are constantly reborn, various types of biofuels coming from biomass, for example, biodiesel, alcohol (methanol and ethanol), biokerosene and many others, and sources for these products can be from either vegetable (e.g. cane sugar and vegetable oils) or animal source (for e.g. chicken fat and tallow) [23].

Chemically, a combination of alkyl esters gives biodiesel which is produced by treating animal fats or the fatty (carboxylic) acids and vegetable oils, industrial, commercial, domestic waste oils and fats of frying processes. these biofuels can be reproduced from numerous tree species such as Babassu oil, Palm, Sunflower, Jatropha, Castor, Peanut, and others [23].

We can highlight ethanol and biodiesel as biofuels which can be employed in IC engines with no need for significant conversions. using these fuels can obtain significant differences in particulate matter emission profile, which will be explained later. The most current concern of emissions is PM because it influences the environment [24]. In these past years, the rules that govern the pollution issuance have pushed automakers to produce cleaner cars and engines. Therefor, fuels from other sources gained large emerged and prominence as alternatives to fossil fuels. various tests have been performed with ethanol and biodiesel to demonstrate the results on emissions, fuel consumption, and engine performance, especially compared to diesel [24,25]. All these types of alternative fuels have brought the researchers' attention because of their matching specifications and enhanced emissions as relation to petroleum diesel [26]. This difference in combustion, emission, and performance of biodiesel are induced by the wide contrasts between these fuels and fossil diesel and its thermophysical and chemical specifications like cetane number, viscosity, density and mainly the oxygen content which is less in diesel than in biodiesel [24].

5. Biodiesel effect on Particule emissions:

The lower cetane number that ethanol has may show poor quality in self-ignition for explicit application of this fuel in real (unmodified) diesel machines. The concentrated octane number is the essential property of ethanol. Adding ethanol to the fuel increases the octane number of fuel and lessens the knock phenomenon, with no effects on the catalytic converter efficiency [27]. Indeed, the first automobile that was built by Henry Ford (Model T), was designed to operate on both pure ethanol and gasoline [28].

Several practical researches indicate that diesel/ethanol mixtures could remarkably lessen particulate matter and smoke. Table 1 illustrates some studies findings regarding PM emissions based on biodiesel/diesel mixtures. In wildly extensive research on the effect of applying biodiesel in the PM emission, the concentration, size, and particle number are marked to have been instantly impacted by the percentage of biodiesel mixed with diesel, the running engine loads, along with fuel treating strategies utilized.

Younga et al. [32] obtained that at 0% load the PM disbandment size varied from the rest experimentals and was found to be bimodal, delivering a dominant core of 15 nm and a considerably insignificant soot mode of approximately 68 nm. At more than 25% load it led to a disappearing core mode. Rather, an unimodal disbandment size was observed with rising the soot mode size and concentration by rising the load gradually from 25% to 75% (Figure 3) [32].

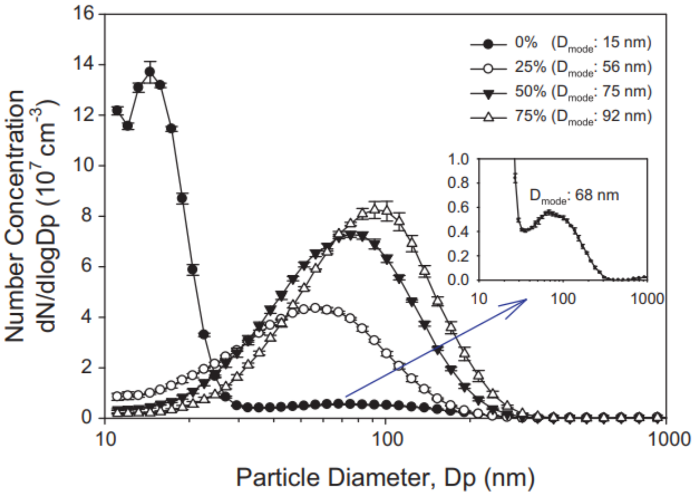

Figure (3): Particle Average size distributions in pre Diesel Oxidation Catalyst (DOC) plus Diesel Particulate Filter (DPF) exhaust at different engine loads using B2 [32].

Table 1:

Ref.	Fuel Used	Findings (PM emission)
29	Ethanol 10% and 15% with diesel (E10 and E15)	Reduction in PM by 20%-27%
30	Diesel fuel with Ethanol (0%, 5%,... 20%)	Reduction in PM by 30%-40%; As much ethanol was added, the smoke emitted decreased
31	Diesel (83%-94%), ethanol (5%-15%) and additive to enhance cetane number (1%-3%)	Ethanol-diesel 15% mixtures deliver a reduction in smoke and soot mass of 33.3% and 32.5% respectively
32	Waste cooking oil (WCO) with B2, B10 and B20, at engine loads (0%, 25%, 50% and 75%)	At a given load there was a reduction in PM number as biodiesel blend increased;
33	Diesel with cottonseed oil	PM emissions decreased by 24% for mixed fuels.
34	Diesel with soybean	The PM diameter decreased for all blended fuels.
35	Diesel with Jatropha	The PM mass varied from ˜ 22.5-32 mg/m3 for mixed fuel and ˜ 28-40 mg/m3 for diesel.

Figure (4) illustrates the biodiesel amount added to the diesel impact on the particle number concentration. At 0% load, a reduction in core particle numbers was observed as the biodiesel amount increased. At a higher load, particle number decreased as the biodiesel blend increased. Thus, the number decreased by rising the biodiesel percentage was in both soot particles and core particles. This is probably because of several reasons, the less aromatic content, the high oxygen content, the lower final boiling point and the long soot oxidation period of the added biodiesel [32]

Along with the biodiesel concentration in fuel, it is claimed that the source and properties of distributed biodiesel used may influence the number and size of the emitted particles in emission profile. This findings was recorded by Pinzi [36] in his research which indicated different impacts on the molecular structure (represented mainly in chain length and the saturation degree) of fatty acid methyl esters in rapeseed methyl ester oil (RME). Also, the impact of using Exhaust Gas Recirculation in the exhaust profile of the emitted particles was tested (Figures 5 and 6) [36]. The outcomes were correlated with those received by ultra low sulphur content diesel (ULSD).

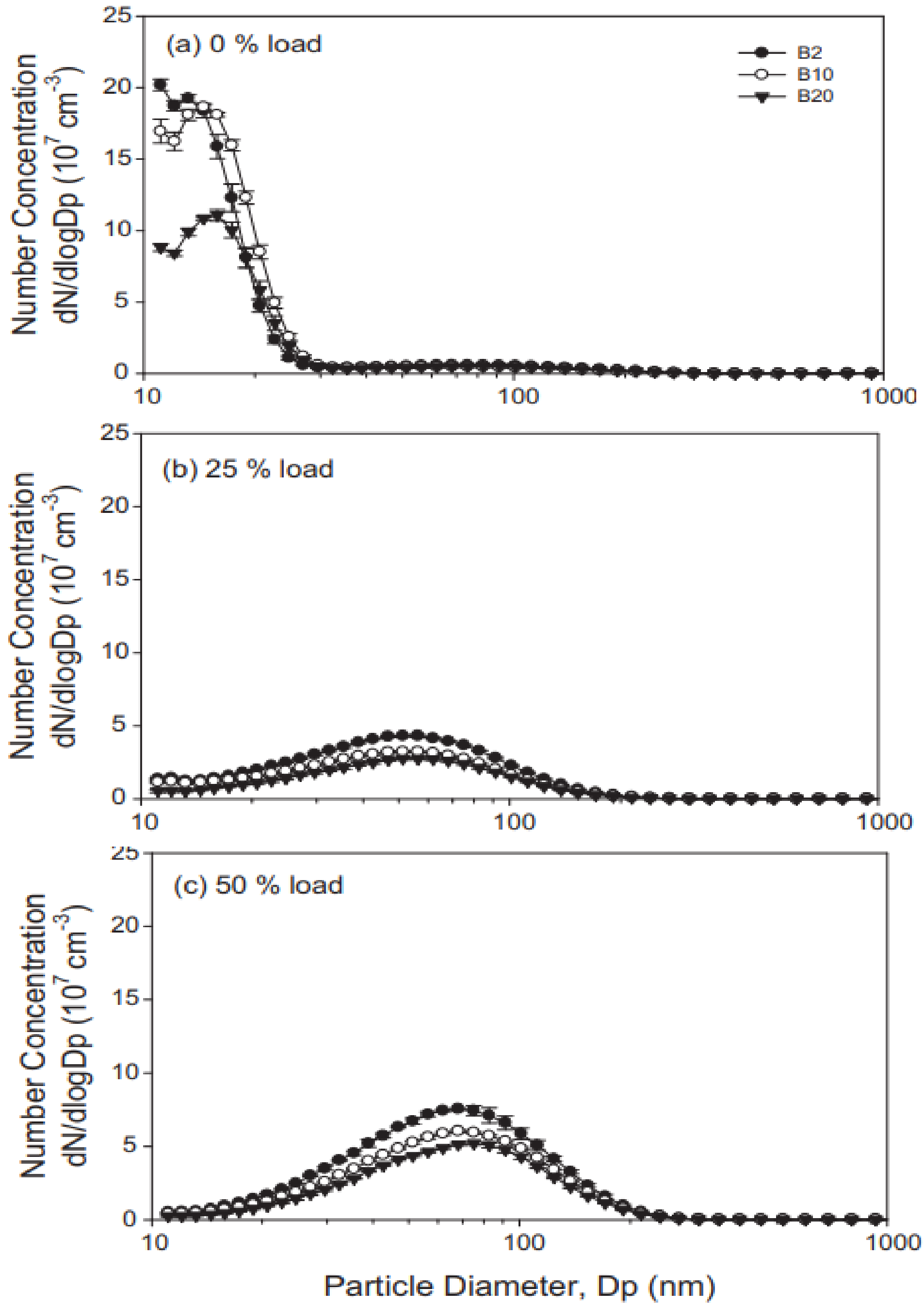

Figure (4): Particle Average size distributions in pre diesel oxidation catalyst (DOC) plus diesel particulate filter (DPF) exhaust at 0%, 25% and 50% load respectively [32].

Via Figures 5 and 6, it was noticed that the finding received by Pinzi et al. [36] demonstrated that distributions size of particles from ULSD fuel are higher and are mostly bigger in shape than the one emitted from RME. All the methyl esters showed less mass emissions (Figure 5) and total number (Figure 6) of the particles compared to the ULSD fuel. In addition, at the EGR stages the particle mass from methyl esters were approximately 60% of the total PM emission coming from ULSD

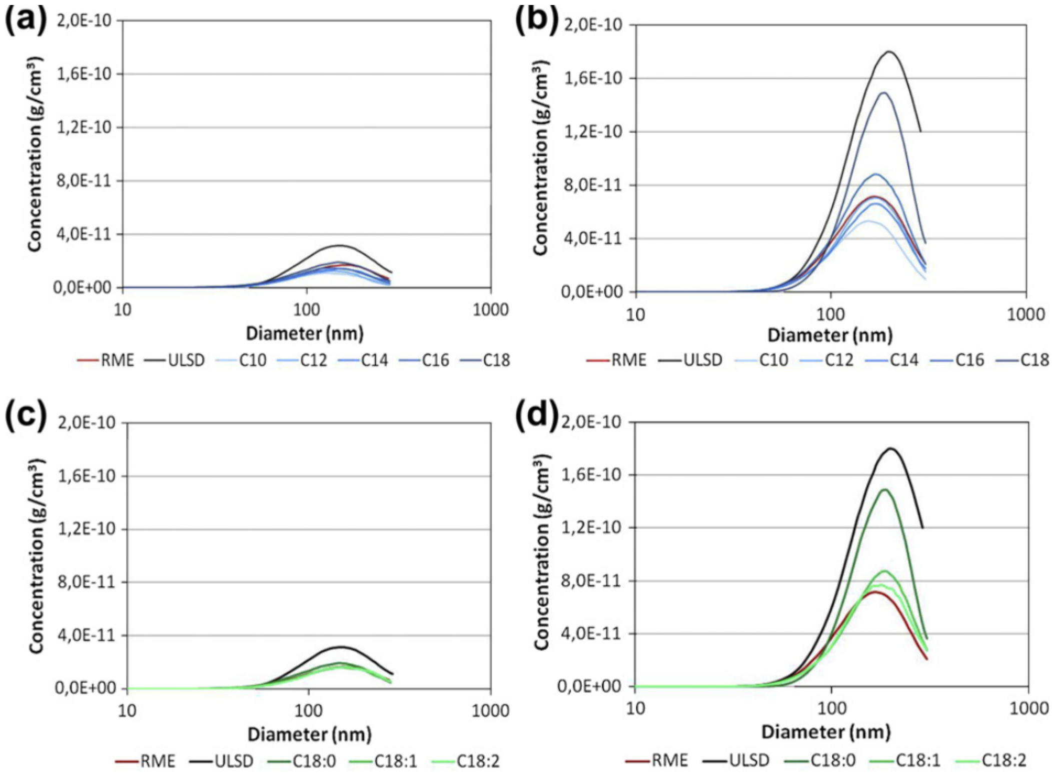

Figure 5: Mass particle size distribution: (a) Chain length impact with 0% EGR. (b) Chain length impact with 30% EGR. (c)Unsaturation impact with 0% EGR. (d) Unsaturation impact with 30% EGR [36].

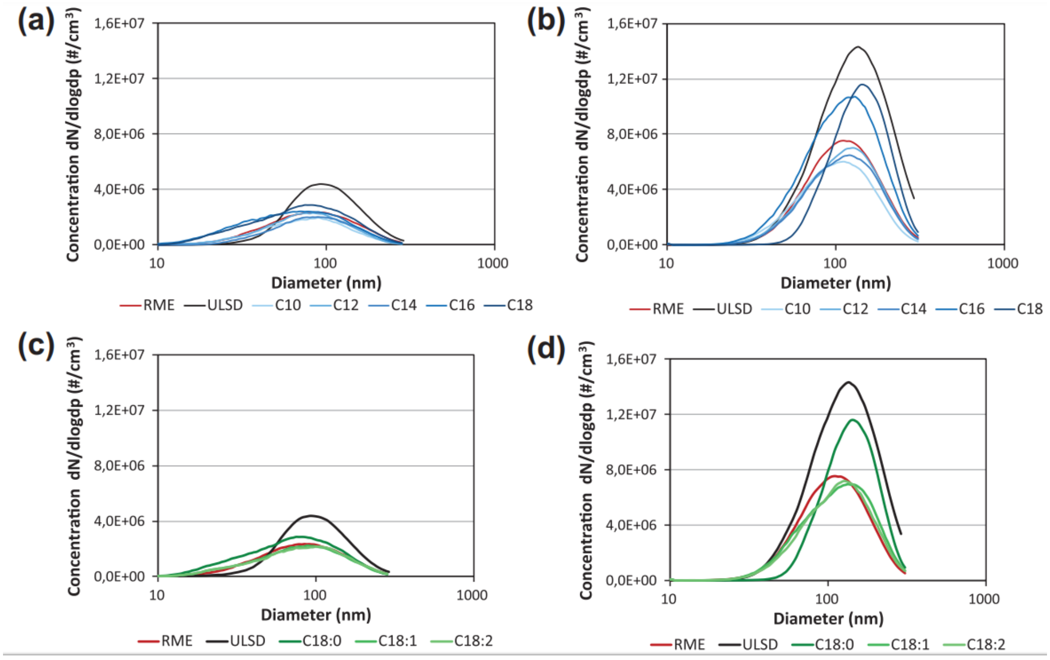

Figure 6: Particle number distribution: (a) Chain length impact with 0% EGR; (b) Chain length impact with 30% EGR. (c) Unsaturation impact with 0% EGR. (d) Unsaturation impact with 30% EGR.[36]

6. Conclusion

The variety in PM features and creation must be taken into consideration during improvement of controlling emission techniques for the evaluation of PM emissions influence on the people's health. Currently, for PM, the controlled value is the total mass. However, PM size and number disbandment provide more details than mass

Independently, this is due to the longer residence time of the small particles in the environment, and are more difficult to trap and more reactive.

Finally, this study aimed to examine the impact of various biofuels on diesel engines PM emissions. Hereafter, the next overall findings are summarized from the above review:

1. The higher viscosity of the biofuel gives insufficient atomization of the fuel producing large soot formed in the combustion cycle. The existence of robust dual bonds between the Carbon and the Oxygene in the biodiesel ester form leads to a smaller amount of carbon, which creates less percentage of soot, hence giving in opposite lower PM emissions amount for the biofuel combustion. Rising the length of fatty acid chain impacts remarkable growth in microscopic particle mode.

2. Even though some investigators have noted a decrease in general Particle number concentration for biodiesel engines and biofuels, there is a growth in the number of microscopic particle modes. which is a real crisis for running engines with biofuels due to the smaller particles sized being more dangerous to human health due to the fact they penetrate more in-depth into the blood cells and respiratory system.

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