Influence of biodiesel-to-diesel addition on major ions and trace elements in fine particulate matter exhausted by a diesel engine

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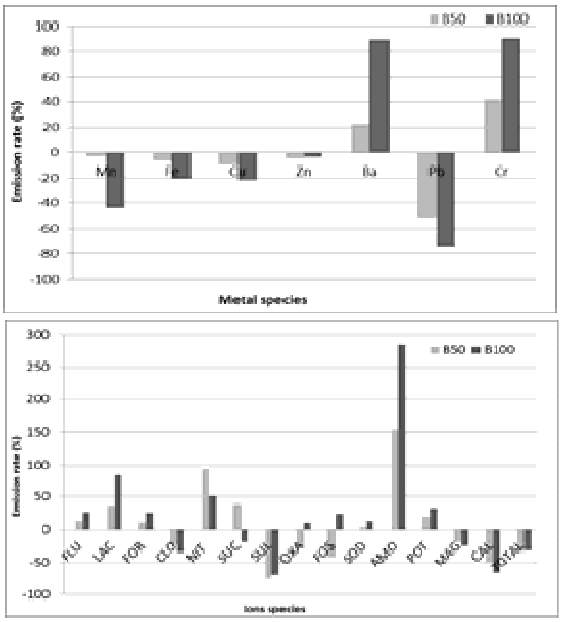
Due to increasing environmental awareness, the decline of petroleum resources and also the rising price of fossil diesel, alternative fuels such as biodiesel are increasingly discussed in many countries around the world (Guarieiro *et al* 2008). Even though the general interest in biofuels as alternatives to petroleum diesel has increased, few studies have been conducted to characterize the chemical composition of fine particles emitted from diesel engines fueled with biodiesel blends.

Fine particles ($PM_{2.5}$) were collected with a diesel engine (Agrale, model M85, 10 HP) coupled to a steady-state dynamometer for sample collection. The emission measurement system was operated based on the constant volume (CVS) principle, and a dilution tunnel (6 m x 120 mm i.d.) was used to dilute the engine exhaust with filtered and scrubbed ambient air. Experiments were run with speed rate at 1800 rpm, operating in a stationary mode and load of 1 kW. Three different fuels were used, in regard to the quantity of biodiesel added (B4, B50, and B100) to fossil diesel. The collection of samples was done by a $PM_{2.5}$ cyclone inlet attached to a holder with a PTFE filter (47 mm d. x 1 µm pore size). Afterwards, major ions analysis (F^-, Cl^-, NO_3^-, SO_4^-, PO_4^{3-}, lactate, formate, succinate, oxalate, Na^+, K^+, NH_4^+, Mg^{2+}, and Ca^{2+}) was done by an ion chromatograph with conductivity detection as well as trace elements analysis (Mn, Fe, Cu, Zn, Ba, Pb, and Cr) was carried out by ICP-MS.

When increasing the amount of biodiesel in the tested fuels there was an increase in fuel consumption. In relation to B4, the use of B50 and B100 caused a rise of 14 % and 20 % of the fuel consumption, respectively. On the other hand, the addition of biodiesel causes a decrease in the emitted $PM_{2.5}$ mass. This reduction is 16 % (B50) and 20 % (B100). This reduction is probably due to a more complete combustion of biodiesel than diesel.

Results of major ions and metals are expressed as emission rate of each species amount in relation to the mass of burnt fuel (Fig. 1). Regarding emission rates for the elements (Fig. 1a), the result can be divided into two groups: one made of the elements that have reduced their emissions with the addition of biodiesel (Mn, Fe, Cu, Zn and Pb) and other group formed by those elements who emission was increased with the addition of biodiesel (Cr and Ba). In the second group, the increases were 89% (Ba) and 90% (Cr) for B100 in comparison with B4.



(a)
(b)

Figure 1. Emission rate (%) for (a) trace elements and (b) major ions in $PM_{2.5}$ emitted by B50 and B100 blends in relation to B4.

When considering total ions (Fig. 1b) similar reductions (30 %) were observed for both B50 and B100. Depending on the fuel used, a rise is observed in emission rate for NH_4^+ (284 %), lactate (85%), K^+ (33 %), formate (27 %), Na^+ (27%) and F^- (13 %). In turn, SO_4^{2-} (69 %), Ca^{2+} (66 %), Mg^{2+} (35 %), and Cl^- (25 %) emission rates were reduced when more biodiesel is added to fossil diesel. Finally, some ions such as succinate, oxalate and PO_4^{3-} were eventually decreased or increased among B50 and B100 fuels, not showing a clear trend. Our results suggest that emissions from biodiesel might be a good fuel choice in terms of $PM_{2.5}$, some major ions (SO_4^{2-}, Ca^{2+}, Mg^{2+}, and Cl^-) and trace elements (Mn, Fe, Cu, Zn, and Pb) but not for the all species studied. Perhaps, addition of a lower amount of biodiesel to diesel may promote benefices in both environmental and human health concerns.

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