Alternative fuel for conventional spark ignition engines based on a standard gasoline, ethanol and other oxygenates

I. Golubkov: Agrofuel AB, St. Göransgatan 160 A, Box 30192, 104 25 Stockholm

A. Hull: Institute for Surface Chemistry, Box 5607, SE 114 86 Stockholm, Sweden*
Department of Physical Chemistry, SE 651 88 Karlstad, Sweden

B. Kronberg: Institute for Surface Chemistry, Box 5607, SE 114 86 Stockholm, Sweden*
Department of Physical Chemistry, SE 651 88 Karlstad, Sweden

J. van Stam: Karlstads University, Department of Physical Chemistry, SE 651 88 Karlstad, Sweden

The use of components derived from renewable raw materials in motor fuel compositions [1], particularly oxygenates [2-7], can reduce the harmful impact of the fuel on the environment. At the same time it should be noted that over the last few years the position of methyl tertbutyl ether (MTBE) as a component for gasolines has weakened considerably [8]. Some countries such as USA and Denmark already prohibit the use of MTBE in gasoline.

In 2003 the European Commission proposed a directive [9] encouraging member states to use biocomponents extensively in motor fuels starting from 2005. The plan is to increase the content of biocomponents in all the motor fuel sold on the European market up to 5.75% by 2010.

Many oil companies producing and selling gasoline believe that ethanol is the solution of the problem of alternative fuel for conventional spark ignition internal combustion engines [10]. In Europe there is discussion about allowing up to 10% by volume of

* Mailing address

ethanol in gasoline instead of 5% permitted by the current EN228 standard. Other companies propose not using oxygenates at all [11,12].

However we share the opinion of those oil companies which are rather critical of the idea of solving the problem of alternative fuel for conventional spark ignition engines either by completely avoiding the use of oxygenates or by using solely ethanol-gasoline blends.

Using ethanol as a component for gasoline has considerable advantages, these are:

- The addition of ethanol to gasoline increases the octane number of gasoline-ethanol blends [13];
- The addition of ethanol to gasoline improves the combustion of the fuel and, as a result, reduces the amount of harmful pollutants in the exhaust emissions [7, 14].

At the same time using ethanol as a component for gasoline has considerable disadvantages, these are:

- The addition of ethanol to gasoline causes an increase in the vapour pressure of the gasoline-ethanol blend. It requires the extraction of the light hydrocarbon fractions from the base gasoline [15];
- The addition of ethanol to gasoline reduces the tolerance of gasoline-ethanol blends to water [12,16];
- The addition of ethanol to gasoline increases fuel consumption.

It is known [17] that blending ethanol with gasoline increases the vapour pressure of the blend compared to the vapour pressure of the source gasoline and even more compared to the vapour pressure of ethanol. A large number of studies are directed to the research of the vapour-liquid equilibrium of the blends of ethanol and individual hydrocarbons [18-28]. However these studies provide rather limited information about the vapour pressure of the blends comprising 10% and less of ethanol mol fraction. The results of our study demonstrate that the vapour pressure of blends of hydrocarbons and ethanol increases considerably specifically at lower proportions of ethanol. Figures 1, 2 and 3 show the variation of the vapour pressure of the ethanol-containing blends for various hydrocarbons, octane, isooctane and o-xylene.

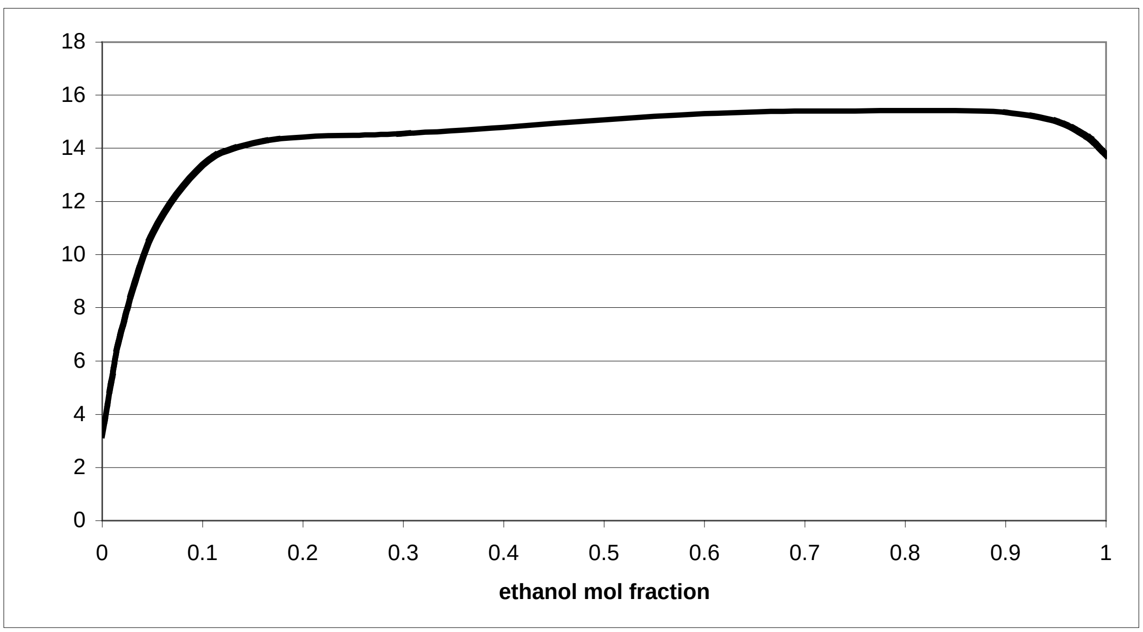

Figure 1. Vapour pressure curve of ethanol octane blends at 35°C for varying concentrations of ethanol.

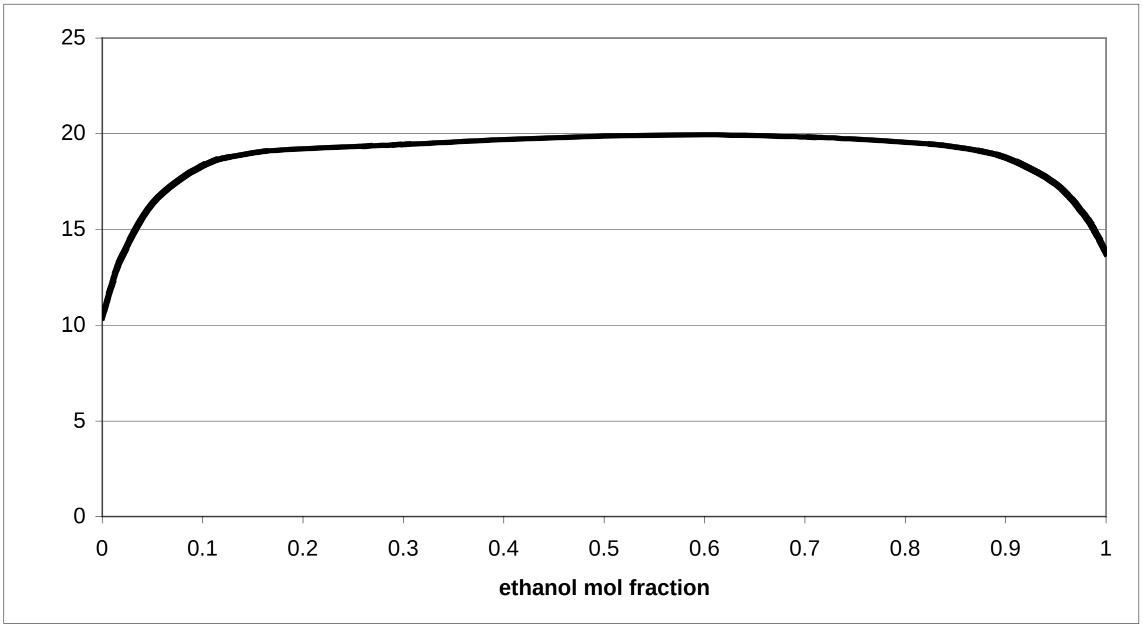

Figure 2. Vapour pressure curve of ethanol isooctane blends at 35°C for varying concentrations of ethanol.

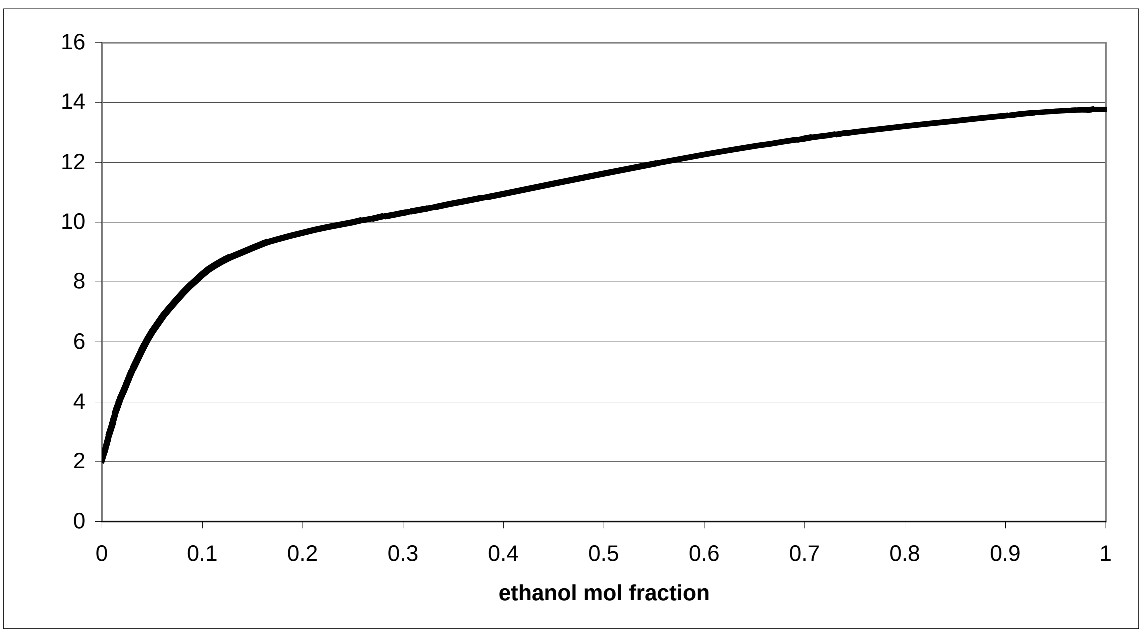

Figure 3. Vapour pressure curve of ethanol o-xylene blends at 35°C for varying concentrations of ethanol.

There are different methods of adjusting the vapour pressure of gasoline-ethanol blends [29-37]. However none of the known methods solves the problem of the vapour pressure of gasoline-ethanol blends containing less than 20% ethanol.

Our inventive method for adjusting the vapour pressure of gasoline-ethanol blends [38] allows the formulation of alternative fuels using standard gasolines as the base, which generally contain light hydrocarbon fractions.

The alternative gasoline compositions which have been developed contain, besides 0.1-20.0% ethanol by volume, other oxygen-containing compounds, including higher alcohols, ethers, esters, ketones, hydroxyketones, ketoesters and heterocyclic compounds in the proportion of 0.05-15.0% volume, and C_6-C_{12} hydrocarbons, including isooctane, isononane, isodecane, unsaturated compounds, including cyclic and aromatics. C_6-C_{12} hydrocarbons can be used either individually or in fractional mixtures boiling within the range 100-200˚C.

The results demonstrate that adding ethanol to gasoline together with other oxygen-containing compounds and C_6-C_{12} hydrocarbons not only keeps the vapour pressure of the gasoline within the requirements of the standard but also increases the octane number and reduces the content of harmful pollutants in the exhaust emissions.

We have performed comparative tests [39] of gasoline blends comprising known octane boosting additives and gasoline-ethanol compositions prepared using the inventive method for adjusting the vapour pressure.

Table 1 Results of comparative tests of gasolines comprising various octane-boosting additives.

Blend composition	DVPE kPa	O_2% W/W	0,5(MON + RON)	CO g/km	HC g/km	NOx g/km	Fc l/100km
GH 100%	58.3	0.0	91.3	7.67	1.01	2.63	10.62
GH 96.8%+Et 3.2%	65.0	1.114	92.0	7.33	1.0	2.7	10.91
GH 95.0%+Et 5.0%	65.6	1.74	92.45	7.36	0.94	2.68	10.91
GH 88.0%+ETBE 12.0%	55.7	1.884	92.5	7.84	0.99	2.64	10.88
GH 90.0% +IO 10.0%	56.4	0.0	92.25	7.80	0.97	2.56	10.78
GH 78.0% + ETBE 12.0%+IO 10.0%	58.3	1.884	92.9	7.60	0.97	2.67	10.93
GH 84.8% + Et 3.2% +ETBE 12.0%	61.6	2.998	93.1	7.34	0.96	2.64	10.95
GH 83.0% + Et 5.0% +ETBE 12.0%	61.8	3.624	93.35	7.25	0.97	2.50	10.61
GH 86.8% + Et 3.2% + IO 10.0%	61.1	1.114	92.65	7.69	1.0	2.54	10.74
GH 85.0% + Et 5.0% + IO 10.0%	61.3	1.74	93.05	7.39	0.98	2.54	10.71

GH 74.8% + Et 3.2% +ETBE 12.0% +IO10.0%	57.1	2.998	93.8	7.29	0.97	2.52	10.76
GH 73.0%+Et 5.0% +ETBE12% +IO10.0%	57.4	3.624	93.85	7.03	0.94	2.46	10.61
GH 76.8%+ Et 3.2% +ETBE 10.0% +IO10.0%	57.6	2.684	93.45	7.16	0.96	2.58	10.66
GH 75.0%+ Et 5.0% +ETBE 10.0% +IO10.0%	57.8	3.31	93.55	7.25	0.94	2.56	10.62

Key:

GH	Commercial Haltermann gasoline	ETBE	Ethyl Tertiary Butyl Ether
Et	Ethanol	IO	Isooctane
		%	% by volume

The experimental data of Table 1 convincingly demonstrate the advantages of the oxygen-containing gasolines prepared using the inventive method.

The component obtained by combining ethanol with appropriate oxygen-containing compounds [38] and C_6-C_{12} hydrocarbons can be blended with any commercial gasoline.

A remarkable aspect of the oxygen-containing gasoline components corresponding to the invention is that all their constituents can be produced from renewable raw materials.

Thus there is a real possibility of introducing to the fuel market an alternative oxygen-containing gasoline containing not more than 2.7% wt. of oxygen, up to 25% volume of biocomponent and suitable for use in conventional spark ignition engines.

We call the component we developed Biological Gasoline Booster (BGB). Properties of the alternative fuels comprising BGB satisfy the requirements concerning conventional gasolines [40].

The results shown below relate to two commercial gasolines Shell A92 and Preem RFG A92 (reformulated gasoline). The alternative gasoline comprised 14.5% BGB and 85.5% base gasoline Shell A92. The other blends tested comprised 85.9% base gasoline Shell A92 and 14.1% MTBE and also 95% base gasoline Shell A92 and 5% ethanol. An ethanol blend comprising 90% base gasoline Preem RFG A92 (reformulated gasoline) and 10% ethanol was also tested.

a. Oxygen content

The oxygen content of the base gasolines was 0%. The oxygen content in the alternative gasoline prepared using a standard gasoline and BGB is somewhat higher than that of the gasoline-ethanol blend comprising 5% of ethanol and less than that of the blends comprising MTBE. The blend of RFG and 10% ethanol cannot be used in Europe because of its high oxygen content (3.5%) but can be used, for example, in some of the states of the USA.

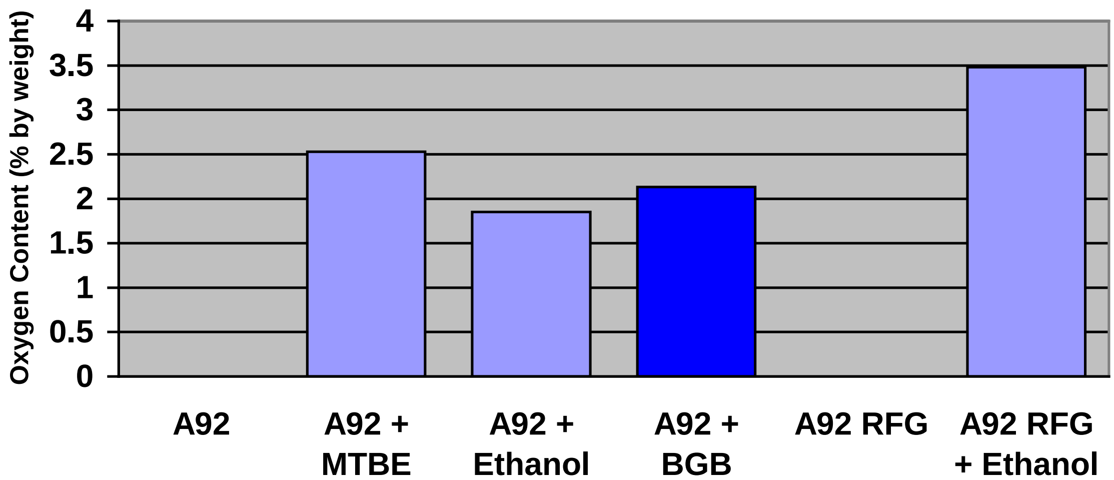

Figure 4. Oxygen content of the gasolines tested

b. Octane number

The octane number of the alternative gasoline comprising BGB is 95.6, that is 3.8 higher than the octane number of the non-reformulated base gasoline A92, which was 91.8. In this case the alternative gasoline was composed to obtain a gasoline with the octane number of at least 95.

The octane number of the alternative gasoline containing BGB is higher than the octane number of the gasoline comprising MTBE and gasoline-ethanol blends. Also the difference between the alternative fuel comprising BGB and gasoline-ethanol blends should be noted.

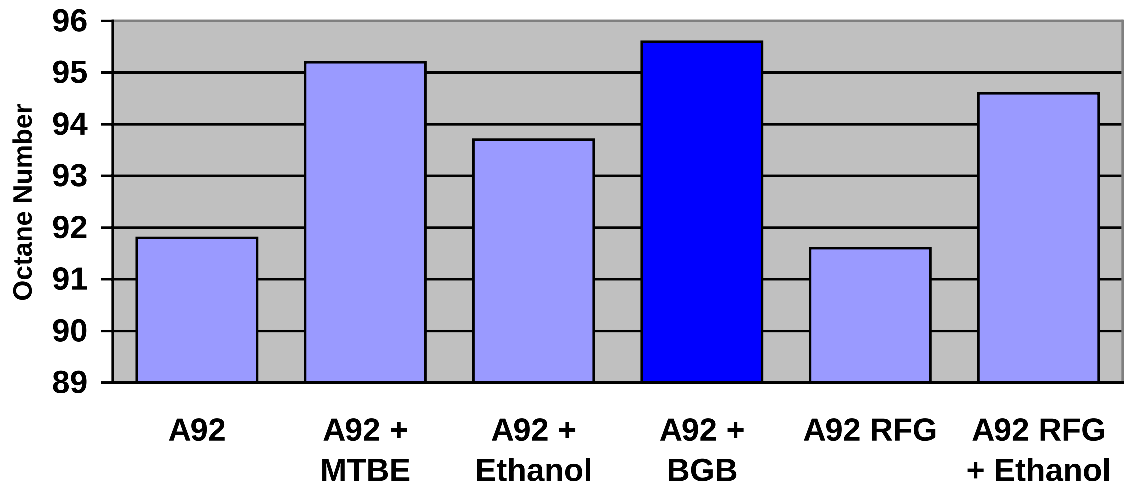

Figure 5. Octane number of the gasolines tested

c. Vapour pressure

The alternative gasoline comprising BGB affects dramatically the degree of the vapour pressure reduction. The results shown in figure 6 relate to the summer grade gasoline. The effect of the presence of ethanol in gasoline-ethanol blends, namely a considerable increase of the vapour pressure in comparison to the base gasoline, is shown in figure 6. For example in these tests the increase is more than 10%. However the alternative gasoline comprising BGB shows a reduction of the vapour pressure in comparison to the base gasoline by almost 5%.

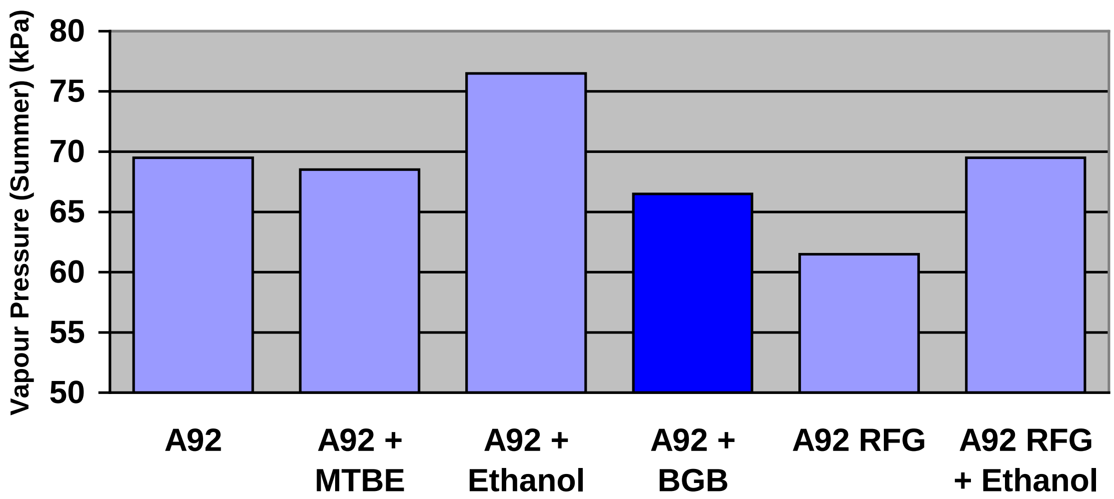

Figure 6. Vapour pressure of the gasolines tested

d. Fuel consumption

The fuel consumption of the gasoline blends comprising oxygen-containing compounds is in general higher than that of the base gasolines. The reason for this is the lower energy content of MTBE and ethanol. However, alternative gasoline comprising BGB demonstrates excellent fuel consumption, better than the base gasoline itself.

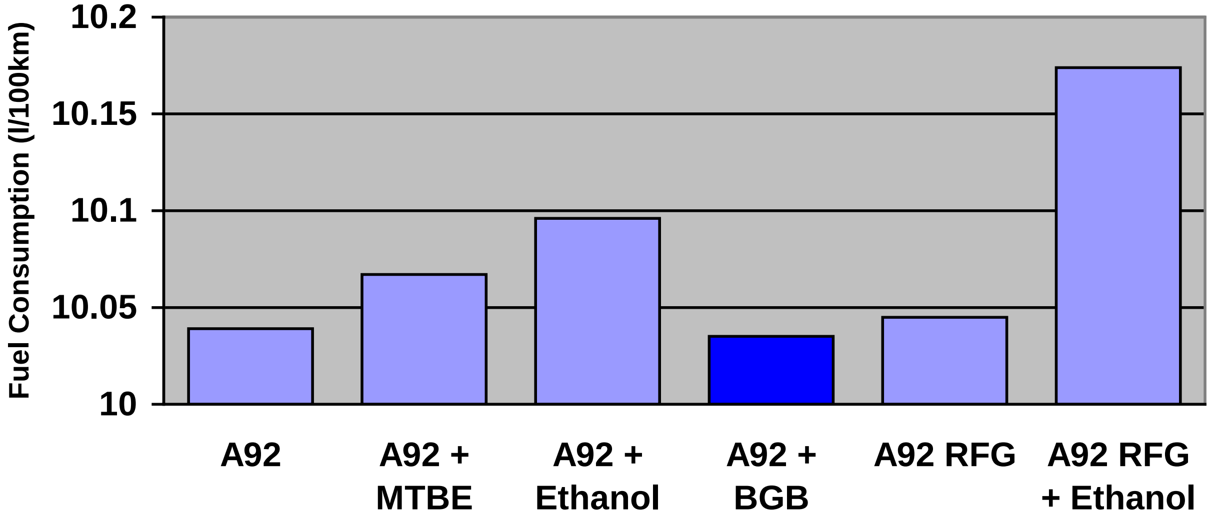

Figure 7. Fuel consumption of the gasolines tested

e. Carbon monoxide emissions

The carbon monoxide emissions of the alternative gasoline comprising BGB are even better than those of the base gasoline being 25% lower. This is better than for the blend of gasoline and 5% of ethanol and for the blend of gasoline and MTBE. For the blend of RFG base gasoline and 10% ethanol this property is marginally, by 4%, better compared with the alternative fuel comprising BGB, but this can be explained by the lower CO emission of the RFG base-gasoline compared to the carbon monoxide emissions of non-reformulated base gasoline. In fact the reduction of carbon monoxide emissions for the blend of RFG and 10% of ethanol is 21%, which is somewhat lower than the reduction for the blend of BGB and non-reformulated gasoline.

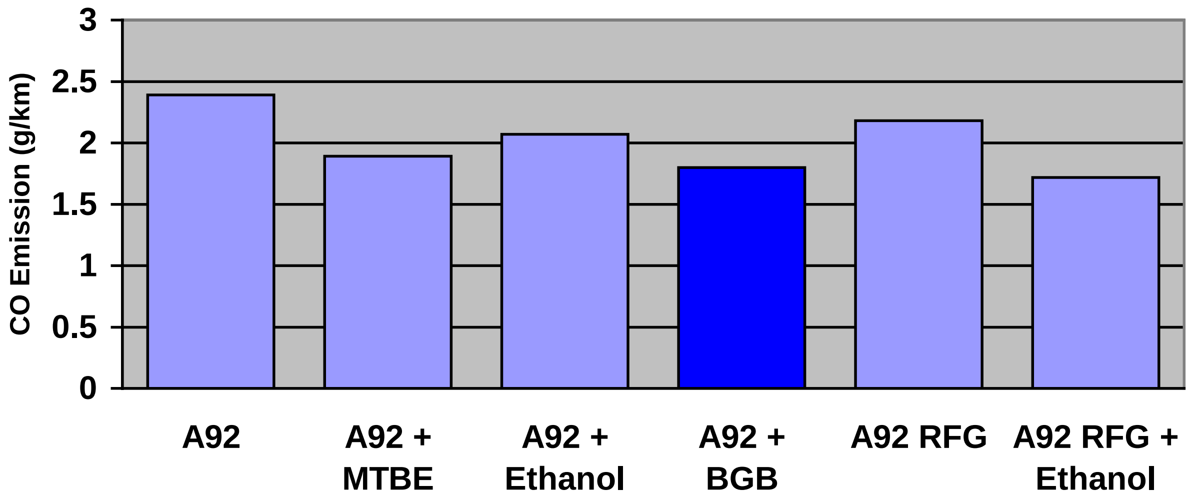

Figure 8. Carbon monoxide content in the exhaust emissions of the gasolines tested

f. Nitrogen oxides emissions

The alternative gasoline comprising BGB shows a considerable reduction of nitrogen oxides (NO_x) emissions.

The reduction of NO_x emissions for the alternative gasoline comprising BGB is:

- 16% compared to the non-reformulated base gasoline;
- 10% compared to the blend of non-reformulated base gasoline and 5% ethanol;
- 7% compared to the blend of non reformulated base gasoline and MTBE.

It should be noted that gasoline-ethanol blends do not have similar reducing effects on NO_x emissions.

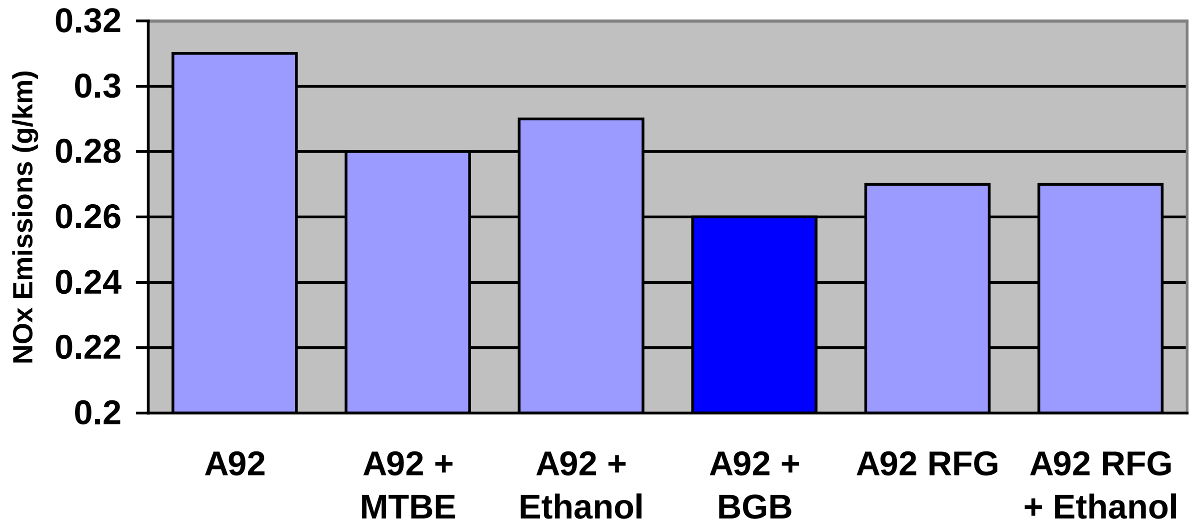

Figure 9. NO_x content in the exhaust emissions of the gasolines tested

Various products of biological origin, including terpene hydrocarbons obtained in the production of pulp, biogas obtained in the utilization of the organic waste, and bi-products of ethanol production can be used for producing the BGB component. We have developed a new method for producing higher oxygen-containing compounds and hydrocarbons based on the fermentation of carbohydrates [41]. The method allows a 1.5 times reduction of carbohydrates consumption for producing fuel components and can be incorporated in the existing ethanol plants.

Conclusions

The results of the research show that:

- The generic biocomponent (BGB) maintains all the advantages of ethanol, that is the ability to increase considerably the octane number of gasoline and reduce the amount of harmful pollutants in the exhaust emissions of engines operating on such blends;
- In contrast to ethanol it does not increase the vapour pressure of gasoline-ethanol blends, has a better tolerance to water and does not increase the fuel consumption.

E-mail address(es):

Angelica Hull angelica.hull@surfchem.kth.se

Igor Golubkov sv.technoferm@swipnet.se

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