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THEORETICAL ESTIMATION OF THE ENVIRONMENTAL IMPACT OF BIOFUEL MIXTURES

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Abstract. Vehicles are burning fuels inefficiently. Nowadays, there is a strong correlation between CO_2 emission and climate change. The article estimates a theoretical environmental impact of biofuel mixtures on the transport sector. A high ratio of road transportation in CO_2 emission caused by humanity made necessary to research the estimation of the environmental impact of biofuel mixtures. We have to clarify the emission of the transport sector in order to get information about the role of the impact that is a further step to a sustainable society. Sustainable development is a kind of development where the pace of technical development, the satiation of increasing supply and the raw materials and resources of the Earth are poised so that the rate of living and the opportunities of the future generations should not decline. One of the major goals of transport policy of the European Union is sustainable mobility. For this reason, transportation systems must be developed and standardized and the effectiveness of transportation service must be increased while environmental pollution must be decreased or prevented. There is a justifiable demand put forward by the society to moderate the environmental impacts caused by road transportation. This article deals with modelling the environmental impact of ethanol-gasoline mixtures and diesel oil-ethanol-biodiesel mixtures.

Keywords: biofuel, ethanol, biodiesel, environmental impact.

1. Introduction

In the last few thousand years, nature has given a stable base of living and almost infinite supply to reserve the biosphere to humanity. In the early ages, humanity made changes to the environment with limited technology, but the rate was infinitesimal compared to the size of the natural environment. Global changes were not detected.

In the last two or three hundred years, there has been an explosion in the development of the industrial and technical sector that supplied people with a multiplied set of tools to encroach nature. The motorization has been developed so dynamically that the air, soil, water pollution is considerable to the amounts of those found on Earth.

Sustainable development is a kind of development where the pace of technical development, the satiation of increasing supply and the raw materials and resources of the Earth are poised so that the rate of living and the opportunities of the future generations should not decline.

Transportation cannot be replaced because it is a part of the production chain. Societies are horizontally and vertically differential. The manpower, stock and semi finished and finished products must be transported.

The importance of the transportation sector is indicated by sector production which is 10% of the GDP of the European Union and more than 10 million people are working in this sector. One of the most emphasized goals of the transport policy of the European Union is sustainable mobility. Trends in almost all sectors of economy will affect the transport sector. In other words, growth in economy automatically leads to growth in transport. There cannot be economic growth without the availability of transport. The role of economy has always been the creation and distribution of wealth. To attain this goal, it is indispensable to possess the means of transport that will permit the intensification and internationalization of exchanging goods and services. At the moment, it is not possible to decouple economic growth or growth in road transport. However, even a more important point is a possibility of decoupling growth in road transport from its environmental impact. Therefore, transportation systems must be developed and standardized and the effectiveness of transportation service must be increased while the environmental pollution must be decreased or prevented. One of the possibilities could be the use of biofuel mixtures (Kugelevičius *et al*. 2007; Raslavičius and Markšaitis 2007; Lingaitis and Pukalskas 2008a, b). The

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above mentioned estimation of environmental pollution caused by motor vehicles fuelled by biofuel mixture can be a base of further more precise consumption based emission calculation which is based on experimental researches (Tánczos and Török 2007).

2. Theoretical Estimation of Environmental Impact

Nowadays, taking into account powerful human impact considerable to the size of the atmosphere, the relation can be changed. CO_2 emission caused by humanity raises the global temperature. More than a quarter of the total emission of CO_2 caused by humanity is produced by road transportation that contributes to climate change (Fig. 1). Within the transport sector, road transport market share is the largest and is increasing due to its superior service in terms of greater flexibility, reliability, speed and a lower probability of damage (Török 2007a).

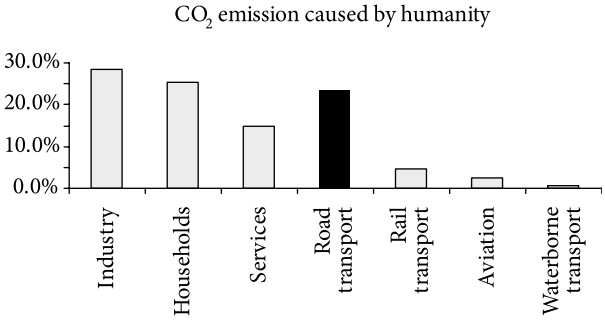

Fig. 1. Road transportation contributes to climate change (Török 2007a)

Protecting the Earth and environment is a common and social will. Figure 2 shows that due to human activity, CO_2 concentration has been dramatically changed (Török 2007b). Global warming is often summarized by the expected global mean temperature increase associated with a certain atmospheric concentration of greenhouse gases. However, the effects are more wide ranging, with the actual temperature rise varying according to the season, day – time and across the regions. Increased evapotranspiration (a term used to describe the sum of evaporation and plant transpiration from the land surface of the earth to the atmosphere) is expected to lead to a mean increase in precipitation, again with actual impact varying in space and time. Beyond this, accurate predictions are difficult to be made. However, it is generally accepted that there will be an increase in extreme weather events. In addition, there is a small but real risk of unpleasant surprises.

It is not desirable to simply ignore low probability events without considering their costs. A view that small probability events would have a negligible impact on expected cost calculation is correct only if the probability falls faster then cost rises. There is a strong connection between environment and road transportation that has effect on the environment by emitting pollutants and greenhouse gases. The environment, in return, has effect on road transportation through climate change.

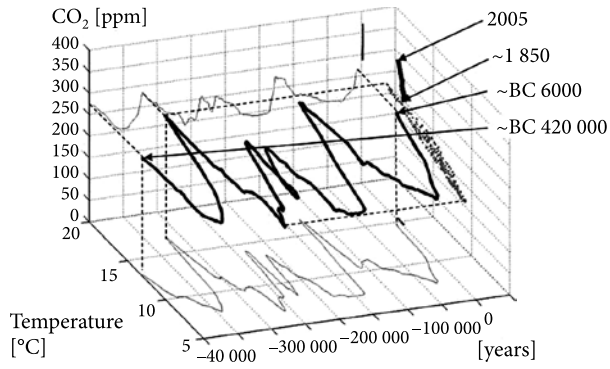

Fig. 2. Average atmospherical CO_2 and average Earth temperature complex time series (Török 2007b)

From this point of view, transportation has to hold on in this dynamic space. Transport plays a valuable role in economic development. An efficient transport system, both of people and goods, enables economy to develop the optimal allocation of scarce resources, thus maximising wealth. The road transport sector is well aware of this essential economic role and of its social responsibilities *vis-à-vis* road safety, labour conditions for the environment, energy saving and consequently sustainable development. It has to fulfil the challenge of environment, society and economy. When developing a policy for transport, this 'sandwich' position of the sector should be constantly kept in mind. The main contribution from transport to climate change is caused by the emission of CO_2. Carbon dioxide emissions are one of the agents responsible for global warming. The volume of CO_2 emissions in the transport sector is directly related to the volume of road traffic and the fuel consumption ratings of individual vehicles. Great strides have been made towards making vehicles more efficient in using fuels, but the progress in this area has been slowing as a result of the currently increased weight (because of safety) and higher average power of vehicles on the roads. A rising level of car ownership in certain countries – which still lags far behind those of the wealthiest countries – suggests that the impact of transport on global warming will remain a major problem. A fuel charge is a good instrument for internalizing the costs of climate change. For this reason, the CO_2 emission of fossil and renewable fuels and their mixture will be estimated.

The base of the presented estimation method is the assumption of a perfect burning of fuels (Pischinger *et al.* 2002) (although gasoline and diesel oil are a mixture of hydrocarbons, however it can be modelled by simplified hydrocarbons as below), although it is clear that perfect burning technically can not be done in reality. For the purpose of the environmental impact, the carbon dioxide emission and the oxygen requirement for the burnt fuels together have been summed. In my estimation, the model I have made is the perfect burning of gasoline, diesel oil, ethanol and biodiesel hereinafter (Török 2007b):

$$2C_8H_8 + 25O_2 \rightarrow 16CO_2 + 18H_2O; \quad (1)$$

$$2C_{14.5}H_{30} + 44O_2 \rightarrow 29CO_2 + 30H_2O; \quad (2)$$

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O; \quad (3)$$

$$2C_{19}H_{38}O_2 + 53O_2 \rightarrow 38CO_2 + 19H_2O. \quad (4)$$

That means, from 114 g of petrol and 400 g of oxygen perfect burning can produce 352 g carbon dioxide, whereas from 204 g of diesel oil and 74 g of oxygen – 616 g carbon dioxide. Employing the same method, the environmental impact of ethanol and biodiesel can be calculated. From 46 g ethanol and 96 g of oxygen perfect burning can produce 88 g carbon dioxide and from 294 g of biodiesel and 848 g of oxygen – 836 g carbon dioxide. When 1 litre of fuel has been burnt, with the density of petrol and diesel oil the maximum amount of CO_2 can be calculated (Table).

The estimation of carbon dioxide emissions from fuels

	Fuel [l]	O_2 requirement [kg]	CO_2 emission [kg]
Petrol	1	2.466	2.161
Diesel oil	1	4.313	3.909
Ethanol	1	1.646	1.509
Biodiesel	1	2.625	2.588

The ideal gas law to convert the mass of oxygen and carbon dioxide to volume has been taken. An ideal gas is defined as one in which all collisions between atoms or molecules are perfectly elastic and in which there are no intermolecular attractive forces. In such a gas, all internal energy is in the form of kinetic energy and any change in internal energy is accompanied by changes in temperature. An ideal gas can be characterized by three state variables: absolute pressure (P), volume (V) and absolute temperature (T). The relationship between them may be deduced from the kinetic theory and is called the ideal gas law:

$$P \cdot V = n \cdot R \cdot T, \quad (5)$$

where: n – the number of moles; R – universal gas constant (R = 8.3145 J/mol K).

One mole of an ideal gas at Standard Temperature and Pressure (Standard temperature: 0 °C = 273.15 K, Standard pressure = 1 atmosphere = 760 mm Hg = 101.3 kPa) occupies 22.4 litres.

3. Correction with the Energy Burned

Although a relative environmental impact of biofuel is decreased because of the extra oxygen added to burning by using biofuel, the difference in heating value has also to be taken into account. Technically, ethanol has less lower heating value (LHV) compared to gasoline ($\Delta LHV_{gasoline\text{-}ethanol}$ = 10 KJ/litre) and biodiesel has nearly the same as diesel oil has ($\Delta LHV_{diesel\ oil\text{-}biodiesel}$ = 0.8 KJ/litre). If the same power demand is assumed, for example, in the case of motor vehicles, then an increase in fuel consumption should be considered.

Fig. 3 indicates that on the horizontal axis, mixtures from pure gasoline (E0) to pure ethanol (E100) with 5% steps of the added ethanol can be seen. On the vertical axes, the environmental impact can be seen without and with corrected heating value. As it can be noticed from Fig. 3, the heating value corrected an environmental impact of ethanol-gasoline mixtures that are nearly equal to the environmental impact of gasoline. It means that a relative lower environmental impact corrected by the consumption (derived from the heating value) leads to nearly the same environmental impact.

Fig. 4 discloses the horizontal axis where mixtures from pure diesel oil (D100E0B0) to pure biodiesel (D0E0B100) with combination of 5% steps of the added ethanol until 20% and 5% steps of the added biodiesel can be seen. On the vertical axes, the environmental impact can be seen without and with corrected heating value. As it can be noticed from Fig. 4, the corrected environmental impact of diesel oil, ethanol and biodiesel mixture has decreased environmental impact with the growing share of biodiesel which can be explained by a relatively small difference in heating value between diesel oil and biodiesel.

Another advantage of biofuels is increasing the diversification of the energy matrix and reducing the reliance of fossil fuel. That will impact energy security, i.e. the availability of energy at all times, in sufficient quantities and at affordable prices. These conditions must prevail in the long term if energy is to contribute to sustainable development. This is a critical subject because of the uneven distribution of fossil fuels resources among the countries (Zöldy 2006).

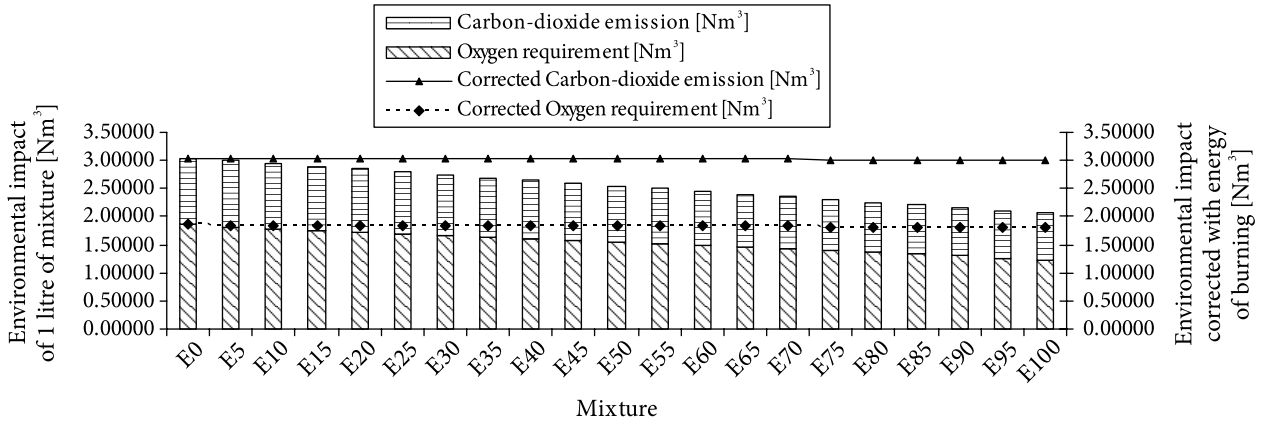

Fig. 3. Environmental impact of ethanol-gasoline mixture

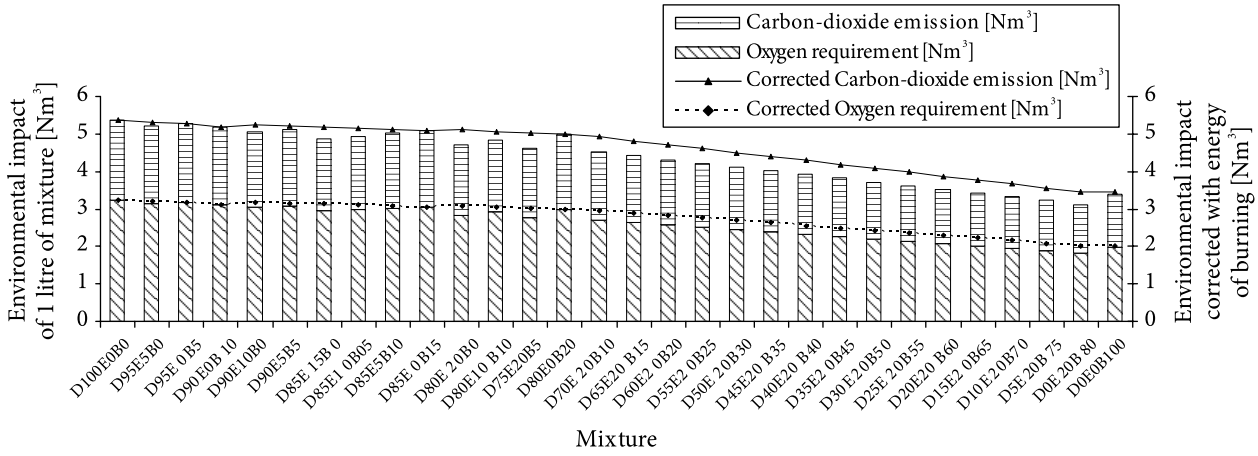

Fig. 4. Environmental impact of diesel oil, ethanol and biodiesel mixture

The World Energy Assessment (WEA) has pointed out that 'views on the long-term availability of oil and natural gas continue to spark controversy and debate'. The current trends indicate that the world will continue to depend on fossil fuels for decades to come, with the largest share of the world's oil resources concentrated in a few areas of the globe. Nuclear fuels are also concentrated in a few countries and nuclear technology raises concerns related to the physical security and environmental aspects of their use.

World market prices for conventional energy sources, in particular oil, are quite volatile. This poses great risks for the economic and political stability of the world with (sometimes) dramatic effects on energy-importing developing countries. In this context, renewable energies, including biofuels can help with diversifying energy supply and with an increase in energy security.

4. Conclusions

1. A high ratio of road transportation in CO_2 emission caused by humanity made reasonable to research relation between road transportation and carbon dioxide emission.
2. There is a justifiable demand by the society to moderate the environmental impacts caused by road transportation. We need to look for the new renewable source of energy for transportation as it is a part of the production chain and cannot be eliminated.
3. Nowadays, considering human impact on the atmosphere, relations can be modified. There are approved technical solutions to substitute fossil fuels in order to reduce environmental impacts. However, there is a question whether it will be effective enough? The estimations show that ethanol does not significantly decrease the environmental impact due to its smaller energy of burn. Only biodiesel gives a good solution in substituting diesel oil. Nevertheless, a renewable source of energy gives the possibility of increasing the international dependency of fossil fuels as it modifies the energy matrix.

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