ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering
Tome VII [2014] Fascicule 4 [October – December]
ISSN: 2067 – 3809

[1.] Slobodan STEFANOVIC, [2.] Imre KISS,
[3.] Gordana BOGDANOVIC, [4.] Damjan STANOJEVIC

ANALYSIS OF FACTORS OF OCCURRENCE OF TOXIC COMPONENTS IN OTTO ENGINE

[1.] Department of Mechanical Engineering, Higher School of Applied Professional Studies,Vranje, SERBIA
[2.] Department of Engineering & Management, Faculty of Engineering – Hunedoara, University POLITEHNICA Timisoara, ROMANIA
[3.] Department of Food technology, Higher School of Applied Professional Studies,Vranje, SERBIA
[4.] Department of Wood Technology,Higher School of Applied Professional Studies,Vranje, SERBIA

Abstract: *A significant portion of the pollution of the atmosphere, and increasing with the increase of their number, a internal combustion engine. In addition to the requirements for the lower emissions of toxic substances in the exhaust of internal combustion engines, we must not neglect the imperative of saving fuel. The combustion of fossil fuels in internal combustion engines consumed more oxygen than the entire human population. Since there is a direct correlation between the consumption of fossil fuels and oxygen consumption, it is expected that fuel consumption will grow by 2.5 to 5% per year.*
Keywords: *toxic - gas components, combustion products, air, otto engine*

1. INTRODUCTION

A significant portion of the pollution of the atmosphere, and increasing with the increase of their number, a internal combustion engine, which is particularly evident in urban areas, areas of developed industry, heavy traffic and communication. One tone fuel combustion in the engine, depending on the type of engine, control, operating mode, the exhaust gases can occur 150-800 kg CO, 7.5-40 kg NOx and 30-100 kg CH.

In addition to the requirements for the lower emissions of toxic substances in the exhaust of internal combustion engines, we must not neglect the imperative of saving fuel.

Combustion products are composed of:

*a) N**on-toxic** gas components, and*

*b) **Toxic** gas components.*

2. MAIN NON-TOXIC GAS COMPONENTS OF PRODUCTS OF COMBUSTION

Nitrogen (N_2) in the motor comes as a component of air, and makes up about 70% of the content of the combustion products. While in the gaseous phase under normal conditions, it is non-toxic and neutral.

Carbon dioxide (CO_2) occurs after the complex mechanism of combustion, and originates from the carbon in the fuel. Its share in the combustion products is 1-16%. During the combustion process resulting water vapor (H_2O) and its share in the combustion products is 2-15%.

In the case when the engine is running with a rich mixture (less air than theoretically necessary) in the combustion products can be found hydrogen (H_2). In case that the engine is running with the lower quality in the the combustion products can be found oxygen (O_2).

In addition to H_2 all these ingredients are complete combustion products, and they can no longer ignite and combusted, so that they do not represent a threat to the external environment and emissions.

The physical and chemical terms, mechanism of formation for these components is very complicated, but it can be simplified display the following formulas:

$$C + O_2 \longleftrightarrow CO_2 + Q \quad (1)$$

$$2H_2 + O2 \longleftrightarrow 2\,H_2O + Q \quad (2)$$

where: Q-heat liberated.

Carbon dioxide (CO_2) is a gas that is not toxic, but with 50% it participates in the occurrence of the greenhouse effect. CO_2 emissions is directly proportional to fuel consumption, because in many countries there is a need for the introduction of legislation in terms of CO_2 emissions coming from the exhaust.

3. MAJOR TOXIC COMPONENT OF COMBUSTION PRODUCTS

Combustion in Otto engines feature undesirable toxic ingredients:

- ✓ *carbon monoxide (CO),*
- ✓ *nitrogen oxides (NOx),*
- ✓ *unburned hydrocarbons (CH),*
- ✓ *odoriferous substances,*
- ✓ *lead (in case of use of fuels with ethyl),*
- ✓ *a compound of sulfur (if the fuel contains sulfur).*

3.1. Carbon monoxide (CO)

Carbon monoxide is the result of incomplete combustion of hydrocarbon in fuel due to a lack of oxygen in the combustion chamber. Theoretically, in the case that the excess air ratio ($\lambda>1$) in combustion products does not have carbon monoxide because it's combustion in the carbon dioxide (CO_2). Significant amounts of CO occur in a rich mixture of the ($\lambda<1$). The cause of the presence of CO during combustion in exhaust gas (stoichiometric and lean mixture) is a consequence of the dissociation of carbon dioxide with a maximum temperature of the work cycle. As for the lean mixture the maximal temperature of duty cycle is lower than the maximum temperature of carbon monoxide (CO) is lower.

One of the lowest reaction formation and combustion of CO is:

$$CO + OH \longleftrightarrow CO_2 + H \qquad (3)$$

Chemical reactions depends on the temperature. Most likely reason for the appearance of the entire exhaust gases at $\lambda > 1$ is a relatively slow process of transformation of CO into CO_2, so that a sudden drop in temperature during the expansion causing freezing reaction started established at higher temperatures. The presence of CO in the atmosphere leads to its binding to the hemoglobin in blood decreases, and its antioxidant properties.

This can be explained by the fact that the binding affinity of the hemoglobin with carbon monoxide is greater than to oxygen for about 240 times. CO concentration of 60-120 ppm blocks 10-20% of erythrocytes. With increasing concentrations of CO, directly influences to the traffic safety because it reduces the rate of reaction, affects drivers' attention, decreasing the work ability of drivers.

Carbon monoxide can be oxidized to carbon dioxide, which is why it requires a large activation energy, so he usually stays in the atmosphere as CO. On the other hand, the carbon dioxide is under very high temperatures decomposes to carbon monoxide and oxygen. In humans and animals, carbon monoxide, block oxygen transport, by binding to hemoglobin to form carboxyhemoglobin. In the normal course of breathing oxygen binds to hemoglobin, building oxyhemoglobin.

However, the carbon monoxide has a higher affinity to hemoglobin than oxygen. Lack of oxygen has detrimental effects on the functioning of all organs, especially the brain. Carbon monoxide is a gas asphyxia, who quickly blocked hemoglobin, which results in rapid suffocation. It is a dangerous gas in enclosed spaces due to accumulation.

The concentration of carbon monoxide by 50-60% in the surrounding air is lethal, whereas 80% of the current causing death. If the organism is exposed to a longer period of low concentrations of carbon monoxide produced chronic poisoning, the symptoms of which are increased pulse, disorders of respiration, blood pressure and reflexes.

In plants which are exposed for a long time to higher concentrations of carbon monoxide is negative effects occur.The adverse effects of carbon monoxide on the plants to amplifyin the presence of sulfur oxides and nitrogen oxides.

3.2. Nitrogen oxides (NO_x)

Resulting from the reaction of nitrogen and oxygen at high temperatures in the combustion process in the engine cylinder. For the concentration of NO_x, in addition to high temperature the oxygen has an important role. The process of oxidation of nitrogen is carried out according to the following reactions:

1. *Entering the nitrogen molecules react with oxygen atoms.*

$$N_2 + O \longleftrightarrow NO + N - Q \qquad (4)$$

(endothermic reaction)

2. *Entry of the nitrogen atom in the reaction with oxygen molecules.*

$$N + O \longleftrightarrow NO + O + Q \quad (5)$$

(endothermic reaction)

The second chemical reaction equilibrium constant is small and the nitrogen oxides formed in this reaction are insignificant. During the expansion, and in extraction operation the resulting atmosphere of nitrogen monoxide reacts with oxygen giving the nitrogen dioxide:

$$2NO + O_2 \longleftrightarrow 2NO_2 \quad (6)$$

Nitrogen dioxide is an odorless gas, red brown color, soluble in water and as such gives a ''acid rain''. Nitrogen oxides in contact with moisture irritant effect on mucous membranes of eyes, nose and respiratory tract.

Nitrogen oxide concentration in the area of the rich mixture (λ> 1), due to the increase in the concentration of molecules and atoms, despite a slight decrease in the maximum temperature of the concentration of nitric oxide cycle and reaches a maximum with impoverishment of the mixture (λ>1, 1) decreases the concentration of nitrogen oxides occurs even excess oxygen due to a decrease of maximum temperature cycles.

Nitrogen belongs to the essential elements, and is one of four biogenic elements. Biogenic elements (C, H, O and N) make up 95% of living matter, and play a key role in the initiation and maintenance of biological systems.

It is involved in the structure and the amino-acid proteins, nitrogen bases, and nucleic acids.

Anthropogenic activity leads to the transformation of nitrogen to oxides thereof that pollute the air. The most important oxides of nitrogen are nitric monooxide and nitrogen dioxide.

In the soil nitrogen is oxidized in the form of inorganic nitrites and nitrous compounds and the reduced form and in the form of organic compounds, some of which are intermediarius in the way of mineralization.

3.3. Nitrogen -suboxide (N_2O)

Nitrogen - suboxideoccurs in soil by microbial activity through denitrification, whereby they can go into the atmosphere or the activity of other microorganisms converted to nitrate. Its concentration in the atmosphere is very small, only a few ppm.

Due to the physico-chemical properties and durability of 20 years, reaches to multiple layers of the atmosphere (the stratosphere). In the lower layers of the atmosphere are in small concentrations, so there is a risk from the standpoint of pollution, but can easily converts into nitrogen monooxide, which contributes to the pollution of the atmosphere.

Table 1. The composition of the exhaust gases

The composition of the exhaust gases		Approximate value	Remark
	Mark	(%)	
Non-toxic gas components	N_2	70-85	Nitrogen from the air
	CO_2	1-16	Ideal product of the combustion of liquid and gaseous fuels
	H_2O	2-15	
	O_2	0-20	The acid from the air at λ<1
	H_3	0-6	Product of combustion
The main gas components	CO	0-15	Combustion at λ<1
	CH	0-2	Unburt hydrocarbons and formaldehyde
	NO	0-0.5	Nitrogen oxides are formed at high temperatures
	NO3	0-0.05	
	CO2	0-0.5	It comes from sulfur in the fuel
	NH3	0-0.2	It occurs in the catalyst

Table 1(continuing). The composition of the exhaust gases

The composition of the exhaust gases		Transparency	Performance	
	Mark		Stimulatory	Toxic
Non-toxic gas components	N_2	Colorless		
	CO_2	Colorless	Low acidic	
	H_2O	Condensing steam		
	O_2	Colorless		
	H_3	Colorless		
The main gas components	CO	Colorless	Odorless	Inhalation poison
	CH	White smoke, blue smoke or colorless	The main causative smell	
	NO	Colorless		Heavy blood poison
	NO_3	The yellow-brown to reddish-brown color	Coughing and irritate the mucous membranes	It damages the lungs
	CO_2	Colourless encourages the formation of aerosols	Irritating odors	
	NH_3	Colorless	Irritating to mucous membranes	

3.4. Nitrogen-monooxide (NO)

By biological path nitrogen monooxide is formed as the oxidative product of metabolism of certain bacteria.

Regarding the sources of anthropogenic pollution of nitrogen monoxide distinguish:

- ✓ *fossil fuels,*
- ✓ *then combustion in industry,*
- ✓ *production of electricity,*
- ✓ *operation of the internal combustion engine (where the high temperature and pressure of elements nitrogen oxidized to NO).*

The concentration of nitrogen monoxide in the exhaust emissions of cars depends on the type of fuel, and driving mode (at higher speeds on the open road, is higher emissions of NO).

Participation of total emissions of nitrogen monoxide percentages like this:

- ✓ *transport (30%),*
- ✓ *power plants (45%),*
- ✓ *industry and domestic furnaces (25%).*

Nitrogen monoxide could be oxidized to nitrogen dioxide, nitrate aerosol, and by photolysisto the gaseous nitrogen.

3.5. Nitrogen-dioxide (NO_2)

Nitrogen monoxide in the air maintains a short time, because of the unstable and quickly subject to oxidation by nitrogen dioxide in the presence of ozone.

Nitrogen dioxide under the influence of sun rays easily decomposed into nitrogen monoxide and atomic oxygen, which by reacting with oxygen produces ozone. If concentrations are not high, these reactions are maintained at an optimum level value of nitrogen monoxide, nitrogen dioxide and ozone.

From the air nitrogen dioxide can be removed by absorption into the soil through the diffusion, by photolytic reactions, or in the form of the compound produced in the secondary air. Of the total annual emissions of nitrogen dioxide 50% comes from transport, 44% of thermal power plants and industry, 6% frees agriculture and combustion of solid waste.

Nitrogen dioxide is a gas of a reddish brown color, pungent odor (sensible already at a concentration of 15 ppm), and is retained for about 3 days in the air. Toxic to the live nature but more toxic than it is his secondary compounds, nitric acid and nitrate peroxy acyl (RAN). Although the half-life of peroxy acyl nitrate for about 1 hour, he is highly toxic to the plants.

Felling of nitrogen dioxide in the air is conducted by the dry and wet deposition (nitric acid). Nitric acid is stable in the gaseous state, and quickly precipitate out of the sulfuric acid.

Since the nitrogen oxides emitted mostly by transportation equipment, they are retained in the surface layer of the urban environment.

4. UNBURNED HYDROCARBONS

Occur as a result of incomplete combustion at rich mixture, and the unfinished combustion (fire extinguisher) for stoichiometric and lean mixture in Otto engines.

The largest portion of unburned hydrocarbons in the Otto engines comes from the boundary layer temperature, the gap between the piston cylinder liner over the first compression ring from a narrow zone displacement between the piston and cylinder head. In a narrow zone near the walls, is large heat losses, which leads to flame extinction.

Of all the hydrocarbon compounds in the creation of aerosols allogeneic elements have major role. They reacted with oxides of nitrogen, and under the influence of sunlight form ozone and other oxidants, all of them have adverse effects on the body.

4.1. The smell of exhaust gases

The smell of exhaust gases derived from aromatic components contained in the fuel and of the individual components of incomplete combustion. Compounds containing an intense smell are both very poisonous, and the occurrence of smell is a warning of danger, per intense scent stand out:

- ✓ *Nitrogen dioxide,*
- ✓ *Partially oxidized hydrocarbons,*
- ✓ *The compounds of sulfur.*

4.2. Lead (Pb)

In the exhaust gases lead comes from tetraethyl and tetramethyl lead, which is added to gasoline as an antioxidant agent. 75% of the lead products of combustion amounts into the atmosphere, of which one quantity deposited on the ground, and about 40% goes as fine airborne particles in the environment, which in conditions of intense traffic poses a risk to human health.

About 25% of lead contained in the fuel is deposited on the walls of the exhaust system, on the walls of the space for combustion and oil for greasing.

Lead found in the exhaust gases occurs in the compounds of phosphorus, bromine, chrome. When lead gets into the body disrupts the function of the digestive system, neuromuscular system and brain. Lead from the body is very difficult to remove and can reach a dangerous concentration.

In the atmosphere reaches the combustion of liquid fuels (additives), from refineries, production processes of steel, lead, zinc, copper and combustion of coal and wood.

Natural sources of lead dust, volcanic eruptions, fires, vegetation, irrigation and flushing of sea mining.

Lead particles are retained for about 10 hours in the air of industrial and urban regions. It can not be transported long distances, and thus is in Greenland measured concentrations of up to 500 times greater than the natural level.

Lead found used in paint industry, installation, batteries and defense industries. Half of the lead produced is obtained by recycling.

The largest source of lead contamination is the primary combustion of gasoline, because it is still used as an additive.

4.3. Sulfur (S)

If in the fuel is sulfur (S), in the exhaust gas can be found sulfur dioxide (SO_2). It is a colorless, encourages the creation of aerosols, and acid rain, which has an impact on deforestation in the country.

Sulfur in the fuel occurs in the form of combustible and non-combustible. Combustible sulfur in the form of sulphate, iron, calcium, in the course of combustion turns into ashes. Combustion sulfur occurs as the organic (within complex organic compounds).

The presence of sulfur in the fuel is highly undesirable because the sulfur is corrosive, and their combustion products is harmful to living world and create acid rain.

Large amounts of sulfur are used in the vulcanization process in which the rubber is transformed into a tire. Natural rubber by treating sulfur loses its stickiness and becomes more elastic. This process takes place at a temperature between 100-150˚C. Depending on the percentage of sulfur is obtained soft or totally hard rubber.

A certain amount of sulfur is in the oil in the soil gas (unprocessed oil and natural gas that is obtained in certain regions contain large amounts of sulfur. By their burning occurs sulfur dioxide and refineries are required to remove the sulfur from it). Sulfur contained in the pure form below soil is dissolving in hot water steam and extracted to the earth's surface it with compressed air. An important source of sulfur is well as its compounds that are found in industrial gases.

4.4. Ammonia (NH_3)

Ammonia is a chemical compound of oxides and nitrogen with molecular formula NH_3. Under normal conditions, ammonia is gas. It is poisonous, corrosive to some materials, is characteristic odor.

Ammonia is used in the production of fertilizers, explosives and polymers. Also ammonia is an ingredient of some detergents for glass.

Liquid ammonia is also used as the solvent. Also ammonia is used in cooling devices. Ingredient with high toxicity resulting from the reduction of NO in the catalyst. In the exhaust gases are present in small amounts to 0.2%. Irritating to eyes and mucous membranes of the respiratory tract.

4.5. Soot

Particles of soot in the air badly affect to the health of people who have problems with the respiratory organs in asthmatics, patients with chronic bronchitis or other. Carbon black is a collection of various compounds that are found in the air. The composition of the soot and varies depending on the composition, carbon black may be a carcinogen and irritating. The composition of the soot is nowhere examined and it is mostly hydrocarbons.

During the combustion of different types of fuel in the engines, in addition to release of the energy is discharged and a large quantity of harmful substances such as carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxide, soot and ash.

In Otto engine, the appearance of soot is linked to work with a rich mixture (little oxygen), whereas under normal conditions of engine running soot occurs in negligible quantities.

Soot particles can absorb various organic and inorganic compounds that are products of incomplete oxidation of fuel and lubricant, where can be very toxic.

5. SOLUTION THAT REDUCES THE AMOUNT OF ALREADY FORMED TOXIC COMPONENTS

Neutralization of the content of toxic components in the exhaust system of Otto engines can be realized by installing thermal, catalytic and combined reactor.

Depending on the application of appropriate fuels these solutions can be divided into two basic groups:

- ✓ *Systems which permits the use of fuels with ethyl,*
- ✓ *Systems that require the application of unleaded gasoline.*

The principles of operation of both of these groups are shown in the following figure I.

6. INSERTION OF AIR INTO THE EXHAUST SYSTEM

Insertion of air into the exhaust system proved to be effective in reducing the content of carbon monoxide (CO) and hydrocarbons (CH). The amount of air depends on the temperature of the exhaust gas. If the temperature can be advantageous to perform post-combustion of these two components in the exhaust system.

The air in the exhaust inserts by a special mechanical pump. The air is inserted as close to the exhaust valve. Insertion of air is combined with thermal insulation channels in the cylinder head and exhaust system. Inserting the inserts in the the special channel, create an insulating air layer, which gives good results.

7. PROTECTION OF AIR POLLUTION

The overall objective is to prevent, reduce or remove any pollution that degrades the environment. Protection of air pollution in residential areas can be achieved by zoning measures, technical and technological processes, as well as maintaining cleanliness of roads and public spaces in neighborhoods proper clearing up of solid and liquid waste.

Zoning measures to protect settlements from air pollution include proper planning and zoning settlements. Zoning protection measures goes back to when the general planning of the entire region selection of the winning features of the relief and the wind rose for the location of settlements, in the location in general and detailed urban plans are extremely important in terms of zoning settlements and provide sufficient surface vegetation. Particular attention should be paid to the choice of location for a residential area as the cleanest part of the settlements and industrial zones as part of the settlement burdened with pollutants. Proper planning of roads is very important, both in relation to the wind rose, and in relation to the frequency of traffic.

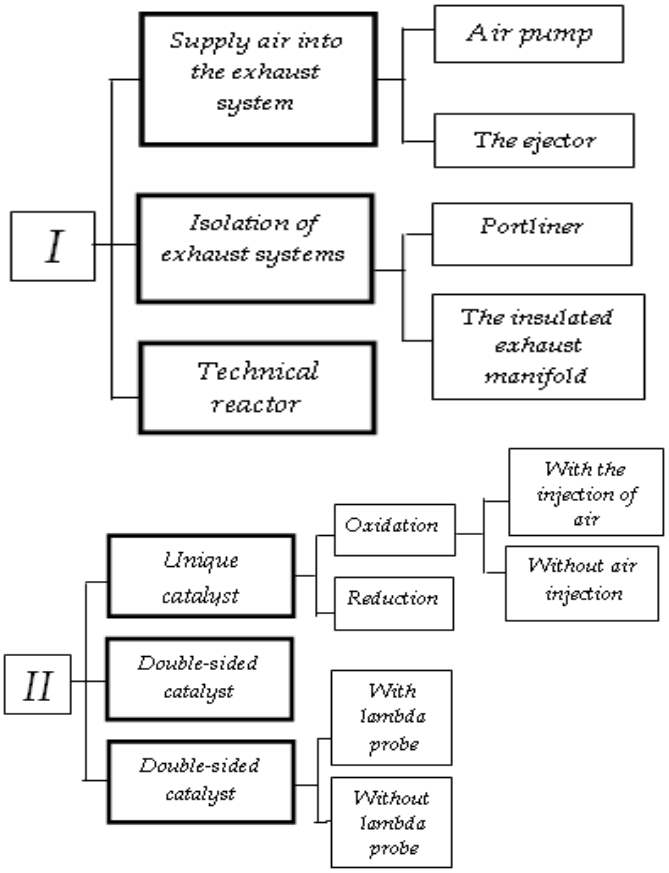

Figure I. Overview of the system to reduce the content of toxic components

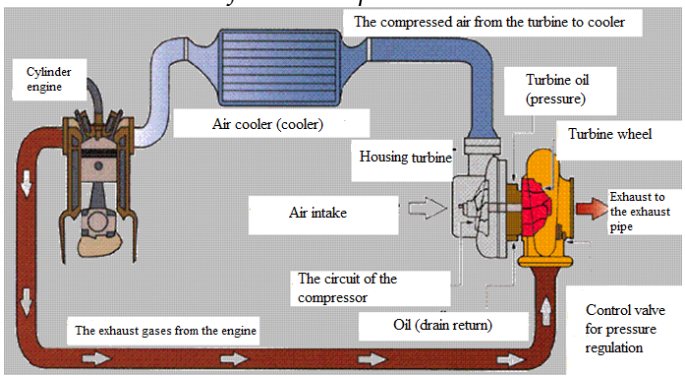

Figure II. Insertion of air into the exhaust system

Technical and technological measures aimed at improving combustion in furnaces, improvement of technological processes of production, with the lowest percentage of waste and emissions of air pollutants. There are a number of technological processes that may be used to protect the air.

Reducing carbon dioxide emissions can be achieved:

- ✓ *selecting an oil which contains less of sulfur;*
- ✓ *desulfurization of fuel and exhaust gases;*
- ✓ *control the amount of air in the combustion;*
- ✓ *reducing hydrocarbon emissions in the transport and processing of fuels (petroleum and its derivatives);*
- ✓ *reducing carbon dioxide emissions by switching to closed production systems;*
- ✓ *removing particles cyclones;*
- ✓ *removing particulate filtration;*
- ✓ *removing electrostatic sedimentation;*
- ✓ *treatment of waste gas absorption;*
- ✓ *catalysts to control emissions from cars; and*
- ✓ *catalytic removal of NO_x and SO_2 from gaseous combustion products*

8. CONCLUSION

The negative impact of traffic on people and the environment, in the work is expressed through the negative external effects of transport (accidents, congestion, capture area, noise, exhaust fumes). These negative effects caused occurrence of certain costs which are defined as the external costs of transport, that man has always avoided factored into the budgets of other costs.

The presence of polluting substances in the air has a number of direct and indirect impacts on the health of all living beings in the biosphere and even the material time. The overall objective is to prevent, reduce or remove any pollution that degrades the environment. Environment for a long time been considered a natural treasure inexhaustible resource that all claimants.

Atmospheric pollution by sulfur dioxide to the fullest extent, is derived from artificial sources of contamination (85% of total emissions), and that:

- ➢ *combustion of fossil fuels,*
- ➢ *operation of thermal power plants,*
- ➢ *oil refineries, and other.*

Once the clean air of the lower atmosphere, which was one of the primary factors in the origin of life and in the human evolution, still has a tendency of significant changes and begins to threaten human. All combustion processes are accompanied by oxygen consumption.

REFERENCES

[1.] G. Bogdanović-Dušanović, D. Nikolić, N. Manojlović, A. Milenković-Anđelković: EKOLOGIJA uzroci i posledice zagađivanja životne sredine, Vranje, 2012.

[2.] D. Nikolić, G. Bogdanović-Dušanović, A. Milenković-Anđelković, N. Dimitrijević, N. Janjić: Zagađivanje sredine izduvnim gasovima, Vranje, 2010.

[3.] B. Milosavljević, R. Pešić, S. Babić : Ekološki aspekti korišćenja motornih vozila.

[4.] M. Zatežić, DŽ. Mujić, I. Bločanin: Saobraćaj i životna sredina u sistemu kvaliteta. Banja Luka, Jun 2009.

[5.] http://www.vts.zr.edu.rs/legacy/images/stories/Predmeti/ekologija/ekologija_zagadjenje_vazduha_konacno_28032011.pdf

[6.] http://www.apeironsrbija.edu.rs/icama2009/034_Momcilo%20Zatezic%20-%20Saobracaj%20i%20zivotna%20sredina%20u%20sistemu%20.pdf

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING
ISSN:2067-3809