Influence of Automobiles on Environmental Pollution

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Abstract. This article considers the influence of automobiles on environmental pollution. It’s been pointed out that the amount of pollutant emitted into the environment depends on the size and the structure of the motor vehicle fleet and the technical conditions of automobiles, namely their engines. Automobiles burn enormous amounts of petrol, thus significantly damaging the environment, primarily the atmosphere, and producing adverse impacts on human health. Vegetation suffers as well because the exhaust fumes from cars immediately affect plants and disturb their natural breathing processes. The use of automobiles leads to environmental pollution and the ecosystem of the entire planet Earth suffers as a result.

1. Introduction

The influence of people on nature is becoming stronger and currently, it can be compared to the impact of natural factors, which leads to changes in the balance of power between the society and nature. That is why today ecology tackles a hard but important challenge of studying the laws that govern the development of the biosphere, elaborating comprehensive development systems for industries and transport alongside with preserving the best environmental conditions. First of all, pollutants can spread within specific components of the biosphere.

The largest amount of atmospheric pollutants come from automobile exhaust fumes. Petrol engines emit more unburned hydrocarbons and the products of their partial oxidation (carbon oxides and aldehydes) than diesel engines. Every car with a diesel or petrol engine that has run 15 thousand kilometres consumes 4,350 kg of oxygen and emits 530 kg of carbon oxides, 93 kg of hydrocarbons, and 27 kg of nitrogen oxides.

Toxic substances are emitted into the atmosphere in exhaust fumes (EF), crankcase fumes, and due to the fuel evaporation. About 2% of the entire volume of EF should be classified as harmful.

Modern automobile engines normally have a closed crankcase ventilation system that virtually eliminates harmful emissions of crankcase gases to the atmosphere. Since the volatility of diesel fuel is an order lower than the volatility of petrol, the problem of evaporation is mostly relevant for petrol engines.

In a wider sense, the negative influence of cars and engines on the environment are connected to their manufacturing and fuel production, as well as the depletion of natural reserves of oil, gas, metal ore and freshwater, which can lead to the changes in the ecosystem conditions.
2. Theory
The automobile is not the only anthropogenic source of toxic emissions into the atmosphere. Large amounts of those come from industrial enterprises, heat and power plants, etc.

The emission of toxic substances due to natural processes (oxidation, rotting, volcanoes, fires, etc.) is significantly higher than that of the anthropogenic sources. However, while nature was adapting to its emissions in the course of long historic periods, the growth rates of harmful emissions from anthropogenic sources provide no such a possibility, which requires relevant measures to be taken to solve this environmental problem.

3. Practical significance
It is a well-known fact that fuel burns in the combustion chamber due to the reaction with oxygen. This process comes with a rapid heat emission that transforms into work. The ignition and combustion of air and petrol mixture (explosive mixture) last for some thousandth fractions of a second, which is too fast: some gases remain in the mixture from the previous cycle and they prevent oxygen from reaching fuel particles, thus preventing perfect mixing. As a result, not all fuel oxidates to end-products, and it is necessary to add more fuel to maintain the normal fuel combustion. If the amount of the fuel in the mixture is above the nominal, this mixture is rich, and if below - it is poor.

Under medium loads, a somewhat poorer mixture comes into the combustion chamber. If the mixture becomes richer, its combustion rate increases and the temperature and pressure in the chamber grow. To tackle maximum loads or a rapid shift from low to high loads, the rich mixture is required. The intensity of fuel feed also increases when starting a cold engine when the mixture is only made of the lightest fuel fractions. In such situations, the fuel does not burn out completely due to the lack of oxygen. The engine produces more power but its work is uneconomical and it emits toxic substances such as carbon oxides, nitrogen oxides, aldehydes and unburnt hydrocarbons into the atmosphere. The most harmful substances include aromatics, such as benzopyrene, that can cause cancer. Besides, the nitrogen present in the air reacts with the residual oxygen in the engine's cylinders because of the high temperature and pressure. As a result, nitrogen oxides are produced, which are one of the harmful components of exhaust fumes.

The amount of pollutants emitted into the environment depends on the size and the structure of the motor vehicle fleet and the technical conditions of automobiles, namely their engines. Just because of the wrong setting of the carburettor in a petrol engine, the emission of carbon oxides may increase 4-5 times.

Table 1 shows the proportions of toxic substances (CO, CH и NOx) in the overall emissions of various sources in a carburettor engine.

| Source                  | CO (o) | CH     | NOx   |
|-------------------------|--------|--------|-------|
| Exhaust fumes           | About 100 | 60...80 | About 100 |
| Crankcase fumes         | -      | 0...20 | -     |
| Fuel fumes              | -      | 20     | -     |

It must be said that the volatility of engines working conditions, a large number of their designs, working processes, types of fuel and the presence of additional units complicate the exact calculation of the permitted maximums of the chemical substances from Table 2 Therefore, the maximum permitted values in Table 3 for some of the more typical exhaust fume components shall be seen as approximate.
Table 2. Exhaust Fume Composition for Petrol and Diesel Engines (in % per volume).

| Exhaust fume components | Petrol engines | Diesel engines |
|-------------------------|---------------|---------------|
| Nitrogen                | 74-77         | 76-78         |
| Oxygen                  | 0.3-8.0       | 2-18          |
| Water vapors            | 3.0-5.5       | 0.5-4.0       |
| Carbon dioxide          | 5.0-12.0      | 1.0-10.0      |
| Carbon monoxide         | 5.0-10.0      | 0.01-0.5      |
| Nitrogen oxides         | 0.0-0.8       | 0.0002-0.5    |
| Hydrocarbons            | 0.2-3.0       | 0.009-0.5     |
| Aldehydes               | 0.0-0.2       | 0.001-0.009   |
| Soot (g/m³)             | 0.0-0.04      | 0.1-1.1       |
| Benzapyrene (mg/m³)     | up to 0.02    | up to 0.01    |

The total amount of harmful substances emitted by car engines can be calculated using the following formula:

\[ G = 0.45MCV, \text{ g/h} \]  \hspace{1cm} (1)

where \( G \) is the total amount of harmful substances;
\( M \) is the molecular weight of the component;
\( C \) is its concentration per volume in %;
\( V \) is the gas flow in m³/h.

To perform a comparative harmfulness evaluation of different complex substances, all of them are normalized against the more studied CO component that shows how dangerous is the carbon monoxide compared to the substance in question. The evaluation of exhaust fume toxicity for various types of automobile engines using the amounts of emissions is not full and objective enough.

Table 3. Concentration Values for Some of the Components of Exhaust Fumes.

| Components                                           | Content by volume in % |
|------------------------------------------------------|------------------------|
|                                                      | Petrol engines | Diesel engines |
| Nitrogen                                             | 74 - 77         | 76 - 78         |
| Oxygen                                               | 0.3 - 8.0       | 2 - 18          |
| Water                                                | 3.0 - 5.5       | 0.5 - 4.0       |
| Carbon dioxide                                       | 5 - 12          | 1 - 10          |
| Carbon monoxide                                      | 1 - 10          | 0.01 - 0.50     |
| Nitrogen oxides (expressed as NO₂, in aggregate)    | 0 - 0.8         | 0.001 - 0.40    |
| Aldehydes (expressed as formaldehyde, in aggregate) | 0 - 0.2         | 0 - 0.002       |
| Hydrocarbons (expressed as methane, in aggregate)    | 0.2 - 3.0       | 0.01 - 0.10     |
| Sulfur dioxide                                       | 0 - 0.002       | 0 - 0.03        |
| Soot                                                 | 0 - 0.04 g/m³   | 0.01 - 1.50 g/m³|
| Benzapyrene                                          | Up to 0.00002   | Up to 0.00001   |

From the point of view of medicine and biology, a comprehensive assessment of exhaust fumes toxicity based on toxicity ratios normalized against carbon monoxide for some of the components is more correct. In this case, the aggregate exhaust fume toxicity is used. To calculate the aggregate exhaust fume (EF) toxicity, \( T_{\infty} \) is assumed to be equal to 1 in the calculations. Here are the values for other components:

\[ T_{CH} = 0.66 T_{\infty}; \quad T_{NOx} = 10 T_{\infty}; \quad T_C = 20 T_{\infty}. \]
Thus, the aggregate emission of the most representative harmful substances can be calculated using the following formula:

\[ T_{OF} = T_{co} + 0.66 T_{CH} + 10 T_{Nox} + 20 T_{C} \]  

(2)

The degree of adverse impact on human bodies of specific toxic substances in exhaust fumes is usually defined by referring to standard limits (LOC). Table 4 shows the LOCs set for harmful substances in the atmosphere and Table 1.5 shows the LOCs for harmful substances in the air of production premises.

According to the sanitary regulations that limit the content of specific exhaust fume components in the atmosphere (Table 4), some dependencies were defined to calculate the aggregate toxicity EF

\[ \eta = n / S_{CO} \sum W_i \zeta_i \]  

(3)

where \( W_i \) is a relative toxicity of the 1st component in the given EF amount.
\( \zeta_i \) is the mass content of the 1st component;
\( S_{CO} \) is the sanitary standard for CO.

### Table 4. LOCs Set for Harmful Substances in the atmosphere.

| Toxic substances | LOC in mg/m³ | One-time | Daily average |
|------------------|--------------|----------|--------------|
| Petrol           | 1            | ---      |              |
| Carbon monoxide  | 6.0          | 1.0      |              |
| Nitrogen oxides expressed as N\(_2\)O\(_5\) | 0.3          | 0.1      |              |
| Sulfur oxides    | 0.5          | 0.15     |              |
| Lead and its compounds | ---    | 0.0007  |              |
| Soot             | 0.15         | 0.05     |              |

### Table 5. LOCs for Harmful Substances in the Air of Production Premises.

| Toxic substances | LOC in mg/m³ |
|------------------|--------------|
| Acrylaldehyde    | 20           |
| Petrol           | 100          |
| Carbon monoxide  | 20           |
| Tetraethyl-lead  | 0.005        |
| Nitrogen oxides expressed as NO\(_2\) | 5          |
| Saturated aliphatics | 300   |          |
| Sulphurous anhydride | 10      |          |

If \( \eta > 1 \), the aggregate EF toxicity, exceeds the standard.

Table 5 shows that the LOC for CO is 20 mg/m³. In this case, the LOC by volume in room air can be calculated using the following formula:

\[ V_{co} = G / M_{co} \times 0.446 \times \% \]  

(4)

where \( M_{co} \) is the molecular weight of the substance;
0.446 is the conversion factor;
\( G \) is the normalized weight content of CO in g/m³;

The harmful impact of automobiles on the environment manifests itself not only in harmful emissions but also in the consumption of atmospheric oxygen that is necessary for fuel combustion in engine cylinders. The amount of air consumed by an engine can be calculated using the following formula:

\[ Q_A = V_1 K n / 2 \times 1000, \text{ m}^3/\text{min} \]  

(5)

where \( V_1 \) is the swept volume capacity of the engine in litres;
\( K \) is the admission factor;
\( n \) is the crankshaft speed in rpm.
Thus, it is possible to evaluate the amounts of EF and their components using the aforementioned formulae. Unfortunately, these formulae do not take the engine operational mode into account, which is crucial for analyzing the EF of fire truck engines. This influence can only be assessed by experiment.

4. Conclusions
There are many ways and methods of preventing the harmful impact of exhaust fumes from car engines on humans and the environment. When selecting a specific one, it is necessary to consider the character of operating the vehicle.

The reduction of exhaust fume toxicity to the permitted maximum values is a complex scientific and engineering challenge. When addressing this challenge, it is important to take into consideration the costs of any respective actions and the requirement to maintain a high efficiency and performance of engines, as well as other parameters.

5. References
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