Effect of average velocity of passenger cars on national annual emission of pollutants

The paper presents the results of the study on the sensitivity of the national annual emission of pollutants from passenger cars to their average velocity under the following traffic conditions: urban, rural, and on motorways and expressways. The study was carried out in accordance with the methodology used in the COPERT 4 software. The effect of traffic speed within cumulated categories of passenger cars on the national emission of pollutants was analyzed. The national annual pollutant emission of pollutants was found to be substantially affected by the average car velocity, this effect being largely differentiated due to the character of road traffic. The type of the dependence of the national annual pollutant emission on the average velocity is similar for all substances, especially under traffic conditions in rural areas as well as on highways and expressways. A distinct minimum of the national pollutant emission was found at a velocity of about 70 km/h under rural conditions.

Key words: motor vehicles, inventory of pollutant emission, COPERT
The study was performed for the automotive situation in 2015. Table 1 shows the values for passenger car traffic in 2015, based on data reported in [1].

Table 1. Values characterizing passenger car traffic in Poland in 2015

<table>
<thead>
<tr>
<th>N_{PC} \text{[mln]}</th>
<th>N_{PC-SI}</th>
<th>N_{PC-CI}</th>
<th>P_{PC-SI} \text{[km]}</th>
<th>P_{PC-CI} \text{[km]}</th>
<th>u_{U}</th>
<th>u_{R}</th>
<th>u_{H}</th>
<th>\nu_{U} \text{[km/h]}</th>
<th>\nu_{R} \text{[km/h]}</th>
<th>\nu_{H} \text{[km/h]}</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.52</td>
<td>14.66</td>
<td>5.86</td>
<td>5900</td>
<td>12300</td>
<td>0.37</td>
<td>0.5</td>
<td>0.13</td>
<td>31.5</td>
<td>70</td>
<td>120</td>
</tr>
</tbody>
</table>

The remaining parameters of the model were assumed in accordance with those suggested by the COPERT 4 software.

3. Results of simulation study

In the paper, the results are presented of three simulations studies – schematic of the studies is given in Table 2.

Table 2. Schematic of studies Nos 1, 2 and 3

<table>
<thead>
<tr>
<th>Study No 1</th>
<th>Study No 2</th>
<th>Study No 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>\nu_{U} \text{[km/h]}</td>
<td>\nu_{R} \text{[km/h]}</td>
<td>\nu_{H} \text{[km/h]}</td>
</tr>
<tr>
<td>21.5</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>23</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>25</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>26.5</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>28</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>31.5</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>36.5</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>41.5</td>
<td>70</td>
<td>120</td>
</tr>
</tbody>
</table>

The average velocity of vehicles was assumed as a variable, respectively, under conditions of urban traffic in the study No 1, under rural traffic – in the study No 2, and under conditions of traffic on highways and expressways – in the study No 3.

The results of the simulation study for selected pollutants are illustrated in Figures 1–21.

There is a significant similarity between the characteristics of the vehicle traffic conditions. For urban traffic conditions, the sensitivity of national annual emission is insensitive to average velocity. For traffic rural conditions, there is a clear minimum national annual emission for average velocity of around 70 km/h. For traffic conditions on highways and expressways, national annual emission is an increasing function of average velocity.
Fig. 5. Dependence of the national annual emission of volatile organic compounds from passenger cars upon the average velocity, under model conditions of rural traffic.

Fig. 6. Dependence of the national annual emission of volatile organic compounds from passenger cars upon the average velocity, under model conditions of traffic on highways and expressways.

Fig. 7. Dependence of the national annual emission of nitrogen oxides from passenger cars upon the average velocity, under model conditions of urban traffic.

Fig. 8. Dependence of the national annual emission of nitrogen oxides from passenger cars upon the average velocity, under model conditions of rural traffic.

Fig. 9. Dependence of the national annual emission of nitrogen oxides from passenger cars upon the average velocity, under model conditions of traffic on highways and expressways.

Fig. 10. Dependence of the national annual emission of particulate matter PM10 from tribological elements of passenger cars upon the average velocity, under model conditions of urban traffic.

Fig. 11. Dependence of the national annual emission of particulate matter PM10 from tribological elements of passenger cars upon the average velocity, under model conditions of rural traffic.

Fig. 12. Dependence of the national annual emission of particulate matter PM10 from tribological elements of passenger cars upon the average velocity, under model conditions of traffic on highways and expressways.
Fig. 13. Dependence of the national annual emission of particulate matter PM2.5 from tribological elements of passenger cars upon the average velocity, under model conditions of urban traffic.

Fig. 14. Dependence of the national annual emission of particulate matter PM2.5 from tribological elements of passenger cars upon the average velocity, under model conditions of rural traffic.

Fig. 15. Dependence of the national annual emission of particulate matter PM2.5 from tribological elements of passenger cars upon the average velocity, under model conditions of traffic on highways and expressways.

Fig. 16. Dependence of the national annual emission of particulate matter from the exhaust system of passenger car engines upon the average velocity, under model conditions of urban traffic.

Fig. 17. Dependence of the national annual emission of particulate matter from the exhaust system of passenger car engines upon the average velocity, under model conditions of rural traffic.

Fig. 18. Dependence of the national annual emission of particulate matter from the exhaust system of passenger car engines upon the average velocity, under model conditions of traffic on highways and expressways.

Fig. 19. Dependence of the national annual emission of carbon dioxide from passenger cars upon the average velocity, under model conditions of urban traffic.

Fig. 20. Dependence of the national annual emission of carbon dioxide from passenger cars upon the average velocity, under model conditions of rural traffic.
4. Conclusions

The simulative study on the dependence of national annual pollutant emission from passenger cars on the average vehicle velocity under model traffic conditions authorize the following conclusions:
1. Despite the differences in the dependencies shown in Figures 1–21, some regularities can be stated. Much smaller differences exist in the characteristics of individual substances than in the conditions of vehicle traffic. There is a substantial similarity of dependence – irrespective of pollution type – for traffic conditions: urban, rural, and on motorways and expressways. The most differing dependencies, among the remaining characteristics, are those for the rural traffic.
2. The highest sensitivity of the national annual pollutant emission to the average velocity of road traffic was found for practically all substances under conditions of rural traffic, while – for some substances – under conditions of traffic on highways and expressways.
3. General conclusions based on the studies conducted show, that the estimation of average velocity values under model traffic conditions, for the purpose of quantifying emission from motor vehicles, can be a source of significant uncertainty in modeling results. This justifies the expediency of implementing an empirical research programme for vehicle traffic on a scale so that it is possible to formulate reliable conclusions about the representative characteristics of passenger car traffic.

Bibliography


Evolution of national annual pollutant emission from motor vehicles in Poland


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