Article citation info:
BEBKIEWICZ, K., CHŁOPEK, Z., SZCZEPAŃSKI, K, ZIMAKOWSKA-LASKOWSKA, M. Evolution of national annual pollutant emission from motor vehicles in Poland. *Combustion Engines*. 2017, **171**(4), 92-96. DOI: 10.19206/CE-2017-416

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CE-2017-416

Evolution of national annual pollutant emission from motor vehicles in Poland

The work analyses the national annual emission of pollutants from passenger cars in Poland, in the years 2000–2015, including the classification of combustion engines relative to the ignition system. The study was carried out in accordance with the methodology used in the COPERT 4 software. The vehicle traffic model was analysed under the following conditions: urban, rural and on motorways and expressways. The national annual pollutant emission was found to change substantially alongside the changes in vehicle properties over the period analysed; the effect varied due to the performance of respective substances. The relative annual national emission of the various pollutants compared to the situation in 2000 were determined. There was a clear declining trend, from 2008 onwards, in the relative annual emission of pollutants from a representative passenger car; this was valid for all substances.

Key words: *motor vehicles, inventory of pollutant emission, COPERT*

1. Introduction

Pollutant emission from internal combustion engines of passenger cars is by far more sensitive to engine parameters and operation conditions than the emission from engines of the other vehicles [5, 10]. This is particularly evident in the case of spark ignition engines [5, 10]. Consequently, the subject of the assessment of the national annual pollutant emission from passenger cars in Poland during the 2000-2015 balancing period was taken into account.

2. The COPERT software

The COPERT 4 software [1, 2, 7–9, 11] was used to determine the national emission of pollutants from passenger cars. This software accounts for a number of data, which can be used to solve a given task including, among others, fuel characteristics and climatic data for a particular country. However, there are also parameters that need to be provided by the user of the programme. These parameters concern elementary categories of cars due to, inter alia, type of engine cycle, type of combustion system, fuel type, engine displacement and ecological level, determined for pollutant emission. The number of passenger cars (Fig. 1) was determined with the use of data contained in the Information System of the Central Register of Vehicles and Drivers (CEPiK) [1].

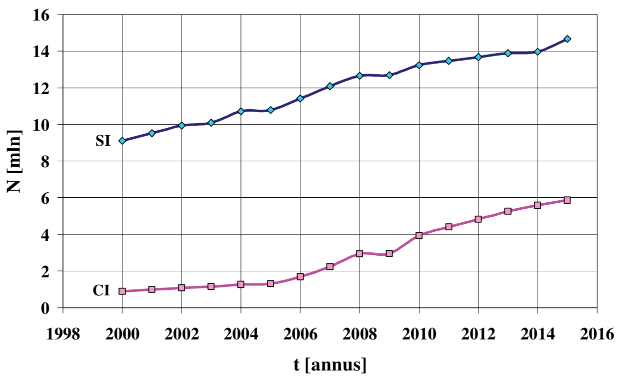

Fig. 1. Number of passenger cars with spark ignition- and compression ignition engines

The vehicle annual mileage provides the measure of the car-use intensity. This mileage was determined, taking into account, among other things [4]: the transport work and the value of technical and operational parameters characterising the work of road transport. Figure 2 shows the annual mileage of passenger cars with spark ignition- and compression ignition engines [4].

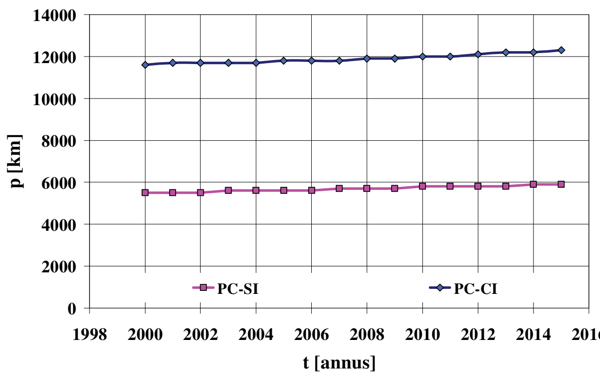

Fig. 2. Annual mileage of passenger cars with spark ignition- and compression ignition engines

A specially developed model of vehicle use intensity, build on the principle of functional similarity, was used to determine the annual mileage of motor vehicles, per elementary ecological categories which are related to pollutant emission. Data on motor vehicle structure at the level of elementary categories were used to identify the model [10].

The description of vehicle traffic [3, 6] was assumed in accordance with the data provided in [4].

Figure 3 shows the mileage of passenger cars under the following model traffic conditions: urban, rural and on highways and expressways; while Fig. 4 – the average vehicle velocity under the above mentioned conditions.

There is a large difference in national annual emission for compression ignition engines and spark ignition engines. Particularly significantly is the national annual emission for cars with spark ignition engines for carbon monoxide and volatile organic compounds. For nitrogen oxides, there is a growing tendency for national annual emission. This is the result of the increasing number of cars with compression ignition engines. Of course, the national annual emission of particulate matter from cars with compression ignition engines is much higher.

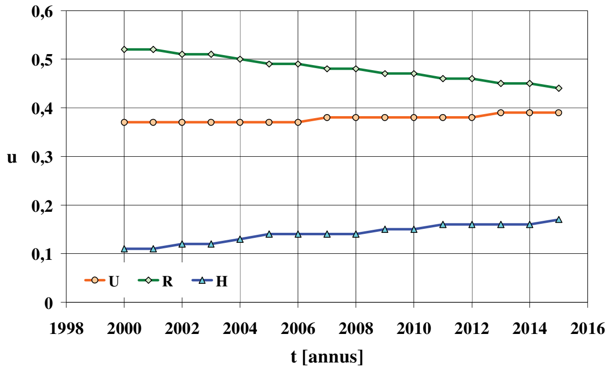

Fig. 3. Mileage of passenger cars under the following model traffic conditions: urban, rural and on highways and expressways

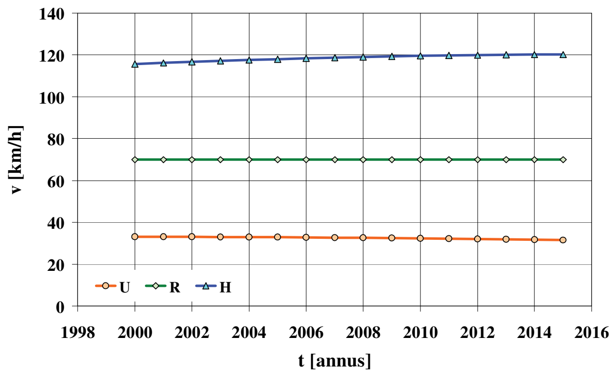

Fig. 4. Average velocity of passenger cars in towns, outside towns, on highways and expressways

The average mileage of a vehicle after engine start, used to determine the cold-start emission, was assumed to be 12 km [1].

3. The results of quantifying pollutant emission from passenger cars in the years 2000–2015

Figures 5–15 show the national annual pollutant emission, by selected pollutants, from passenger cars.

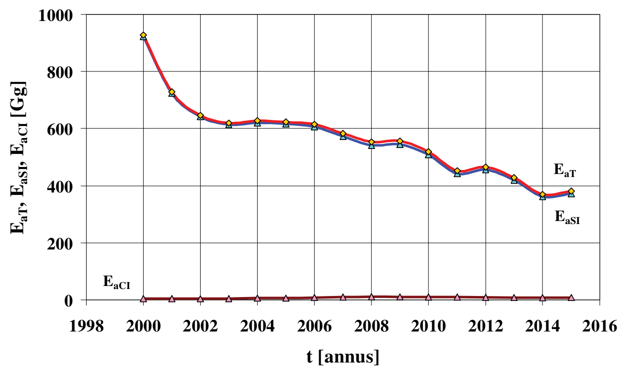

Fig. 5. National annual emission of carbon monoxide from passenger cars

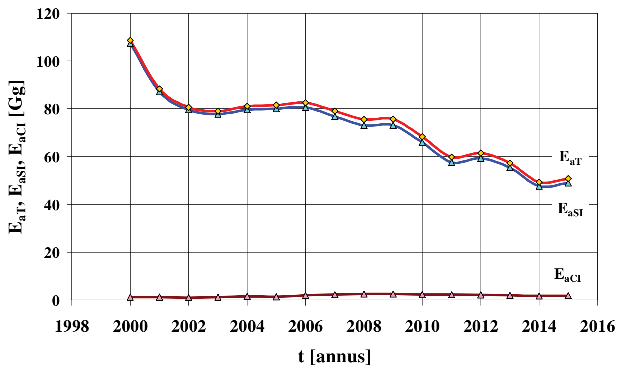

Fig. 6. National annual emission of volatile organic compounds from passenger cars

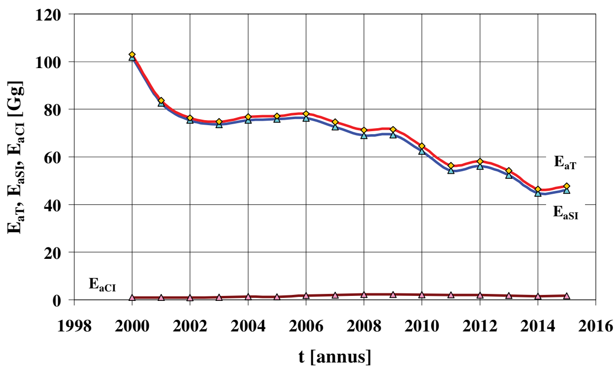

Fig. 7. National annual emission of non-methane organic compounds from passenger cars

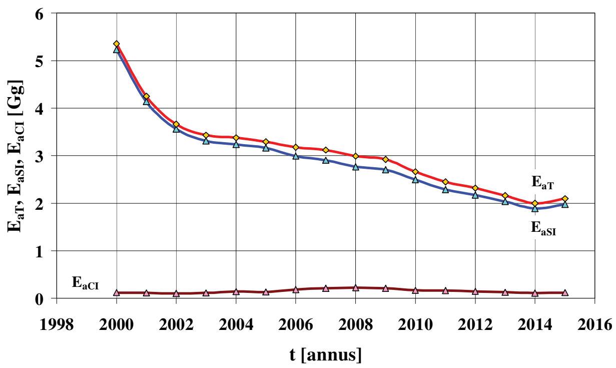

Fig. 8. National annual emission of methane from passenger cars

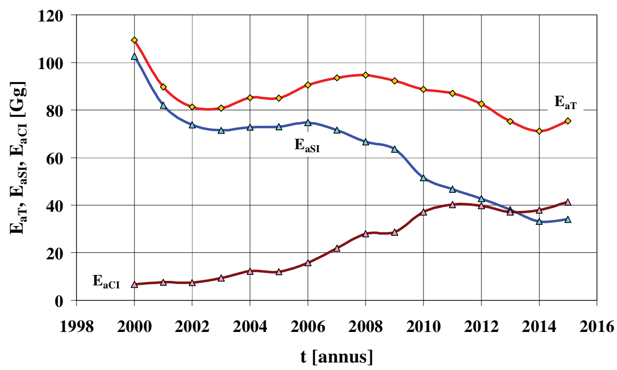

Fig. 9. National annual emission of nitrogen oxides from passenger cars

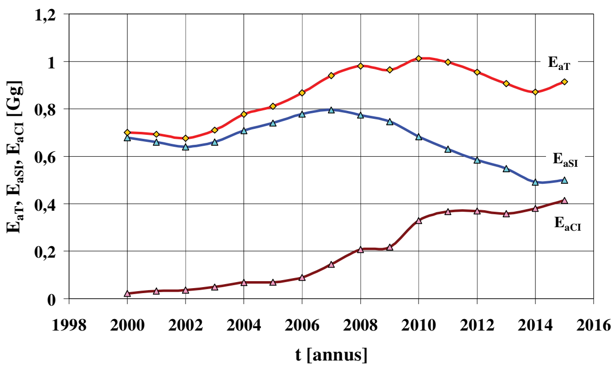

Fig. 10. National annual emission of nitrous oxide from passenger cars

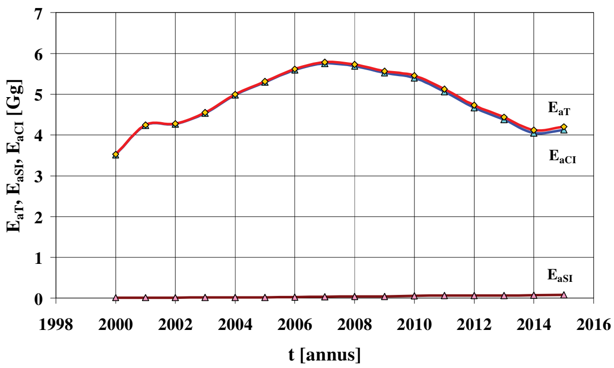

Fig. 11. National annual emission of ammonia from passenger cars

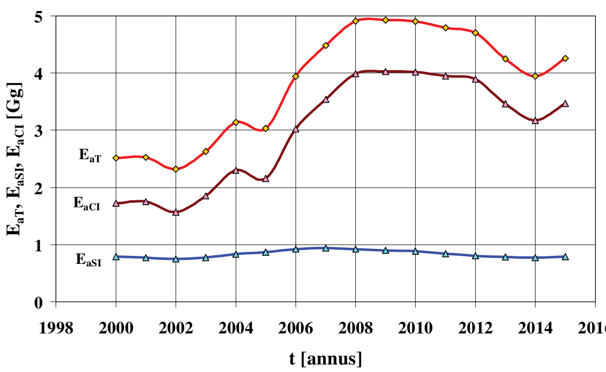

Fig. 12. National annual emission of particulate matter PM2.5 from tribological elements of passenger cars

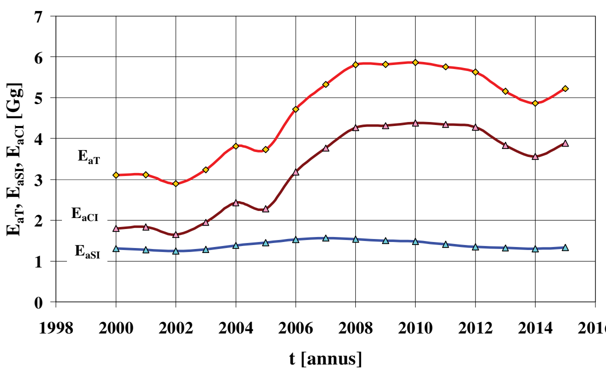

Fig. 13. National annual emission of particulate matter PM10 from tribological elements of passenger cars

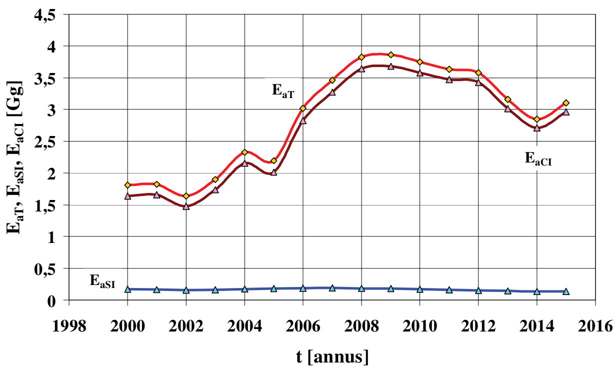

Fig. 14. National annual emission of particulate matter from the exhaust system of passenger car engines

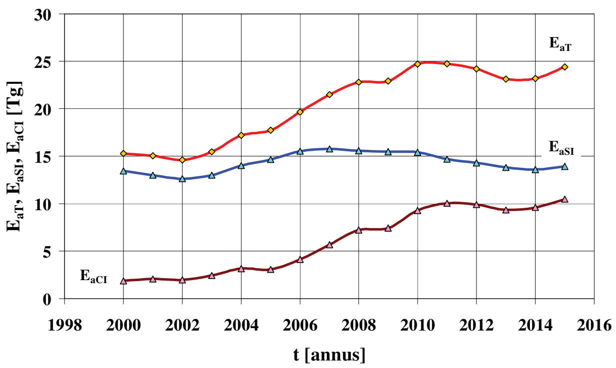

Fig. 15. National annual emission of carbon dioxide from passenger cars

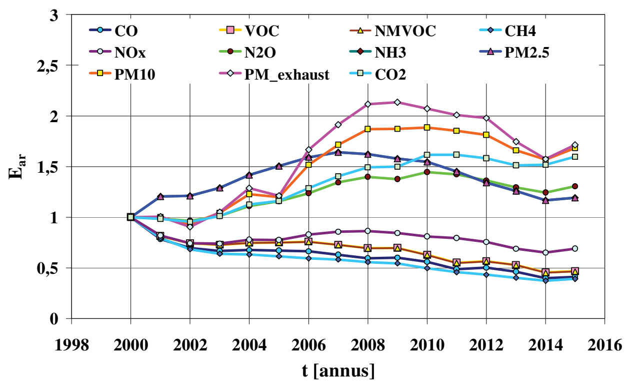

Fig. 16. Relative national annual emission of individual pollutants

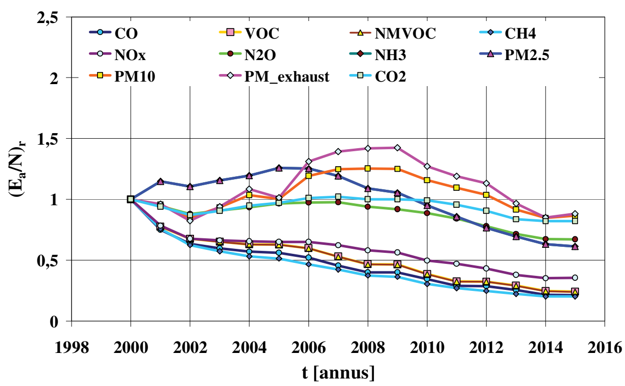

Fig. 17. Relative national annual emission of individual pollutants from a single passenger car

In Figure 16, the relative national annual emission of individual pollutants from passenger cars is presented, relative to the national annual emission in 2000. Whereas, Figure 17 shows the relative national annual emission of individual pollutants from a single conventional passenger car, as compared to the national annual emission in 2000.

4. Conclusions

The following conclusions can be drawn from the results of study carried out on the model of pollutant emission from passenger cars:

1. For the majority of harmful substances, the emission of which is limited by European regulations, there is a clear trend of decreasing national annual emission over the subsequent years of inventory, although the number of vehicles and the intensity of their use increase as the years go by. Apparently, this is evident in the case of carbon monoxide, volatile organic compounds, non-metallic volatile organic compounds and methane. Less evident is this tendency for nitrogen oxides: in the case of spark-ignition engines, there is a decrease in the national annual emission from 2006 onwards, while in the case of compression ignition engines, this emission is increasing, albeit national annual emission for all passenger cars decline since 2008. Annual emission of particulate matter increase until 2008 and then tend to stabilize or decline.
2. For carbon monoxide, volatile organic compounds, non-metallic volatile organic compounds and methane, the national annual emission from compression-ignition engines are considerably lower than those from spark-ignition engines. The opposite relationship is for solids.
3. The national annual carbon dioxide emission tend to increase, which is related to the increase in fuel consumption due to the increase in the number of vehicles and the intensity of their use.
4. The relative national emission from one conventional passenger car have been on a clear decreasing trend since 2008 for all substances, but for most pollutants since already 2005 – despite the rapid increase in the number of vehicles and the intensity of their use. This is the result of technical progress in the development of construction of new passenger cars.

Nomenclature

CH_4	methane
CI	compression ignition
CO	carbon monoxide
PC-SI	passenger cars – spark ignition (engine)
SI	spark ignition
T	total (vehicles)
VOC	volatile organic compounds
C	coaches
CH_4	methane
CI	compression ignition
CO	carbon monoxide
E_a	national annual emission
H	highway
LCV	light commercial vehicles
LCV-CI	light commercial vehicles – compression ignition (engine)
LCV-SI	light commercial vehicles – spark ignition (engine)
Mc	motorcycles
Mp	mopeds
N	number of vehicles per cumulated category
P	annual mileage of vehicles per cumulated category
PC-SI	passenger cars – spark ignition (engine)
R	rural
SI	spark ignition
T	total (vehicles)
t	time
u	share of mileage of vehicles, per cumulated category, under model traffic conditions
U	urban
UB	urban buses
v	average velocity of vehicles per cumulated category
VOC	volatile organic compounds
N	number of passenger cars
N_2O	nitrous oxide
NH_3	ammonia
NMVOC	non-methane volatile organic compounds
NO_x	nitrogen oxides
PC	passenger cars
PC-CI	passenger cars – compression ignition (engine)
PM exhaust	particular matter from exhaust system
PM10	particular matter PM10 from tribological elements of a vehicle
PM2.5	particular matter PM2.5 from tribological elements of a vehicle

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