METHODOLOGICAL ASPECTS FOR ESTIMATION OF IMPACT OF MODERNISATION OF FLEET OF TRACTORS UPON POLLUTING EMISSIONS IN THE AIR

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Abstract. The article provides the summary data on the variations in the areas of the cultivated agricultural land and the amount of fuel consumed in agriculture during a decade, as well as on the investments into the modernisation of agricultural machinery, including the data about the number of the purchased tractors. The consumption of fuel has grown considerably in the period mentioned alongside with an increased number of tractors, the volume of pollutants emitted in the air by them complying with the normatives set by the EU Directive. An analysis is given in the article of the variations in these normatives by periods and a methodological approach is offered how to estimate the total volume of pollutants emitted by the tractor fleet with an aim to find out their changes in a long-time, for instance, a ten-year period. A volume of emissions has been calculated for a tractor produced in different periods of time at the same fuel consumption rate.

Key words: pollutants, emissions in the air, fleet of tractors.

Introduction

Increase of agricultural equipment and high performance of tractor stock influence pollution of the environment by exhaust gases [1]. Poisonous exhaust substances, oil products and their vapour are disposed to the environment [2]. Environmentally-unfriendly impact factors break the ecological balance, decrease the soil productivity and have a negative influence on human health [3]. Moreover, exhaust emissions and their effects on the environment and human health, such as mutagenicity of particulate matter (PM) and ozone-forming potential, must be considered when working out activities for decreasing of them [4].

On the European Union (EU) level emissions from non-road mobile machinery engines, inter alia tractors, are regulated before they are placed on the market by four following directives: the Directive 97/68/EC [5], amended by the Directive 2002/88/EC [6], by the Directive 2004/26/EC [7] and by the Directive 2006/105/EC [8]. Most important of them is the first Directive 97/68/EC [5], which on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery regulates the maximum exhaust emissions carbon oxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulates (PM) from diesel engines installed in construction, agricultural and forestry machinery, railcars & locomotives, inland waterway vessels, constant speed engines and small petrol engines used in different types of machinery. The Directive foresees emissions limit stages of increasing stringency with corresponding compliance dates. Manufacturers must ensure that new engines comply with these limits in order that they can be placed on the market.

Given the economic, security and climate change benefits of reducing fuel consumption there is a significant opportunity for early benefits from the introduction of improved vehicles, especially as the focus of the European legislation is likely to move from emissions to fuel efficiency over the period required to develop significant vehicle technology improvements [9].

An improvement of the use of land – the main agricultural resource – has taken place during the last ten years from 2000 till 2009. The areas of the land used in agriculture have increased by 16 % but the areas under crop by 26 % [10]. Also according to the data of the Agricultural Support Service on the basis of which it is possible to receive area payments, these areas have increased in the years 2004-2009 by 14 % but the areas under crop – by 20 % [11]. The amount of fuel consumed in agriculture in the same period has increased by 50 % [12], therefore it could be expected that the volume of polluting emissions in the air caused by tractors and other self-propelled agricultural machinery might have also increased. However, considerable finances have been invested in this period into modernisation of agricultural machinery – in the period 2002–2008 approximately 136 million LVL were spent as a cofinancing from the EU programmes for the purchase of agricultural machinery [13], approximately 31.2 million LVL as a cofinancing from national subsidies, approximately 83 % of the total sum being spent for the acquisition of the machinery for field crop cultivation [14]. Assuming

that cofinancing constituted approximately 35 % of the total value, one can calculate that in this period about 760 million LVL were spent for the acquisition of agricultural machinery. This means that there has been a considerable increase in the use of tractors and combine harvesters with a lower specific fuel consumption and reduced emissions of pollutants, as well as in the application of contemporary technologies developed for lower specific consumption of fuel. These factors, in their turn, decrease the volume of the polluting emissions. The aim of the article is to offer a methodological approach for the estimation of the impact of the trends mentioned above, particularly modernisation of the fleet of tractors, upon the volume of the polluting emissions in the air.

Materials and methods

The volume of the polluting emissions in the air caused by the machinery for field crop cultivation depends on a series of factors – the cultivated area, the amount of the consumed fuel, which, in its turn, is dependent on the applied technologies and the quality of the tractor engines, and can be characterised by their compliance with the normatives of the allowed emissions set by the EU directives, as well as the technical condition of the tractor engines. The scheme which shows the most important factors affecting the volume of emissions is presented in Figure 1. These normatives, in their turn, are fixed for a certain number of years – a period. The allowed volume of emissions caused by the tractor engines that were produced in the EU during the corresponding period of time (in a 3-4-year interval) is established by the directive [5], therefore it is assumed further that the emissions of pollutants in the air from all the tractors produced in the EU during this period comply with the normatives set by the Directive. It is expected that the next correction of the allowed amount of emissions will take place in 2013. But the data about the number of the purchased tractors by years and brands can be found in the reports of the State Agency of Technical Supervision [14]. The data about the cultivated area can be obtained from two sources – the annual reports of the Central Statistical Board under the title "Latvijas lauksaimniecība 2000. …2009 (Latvian Agriculture)" [10] and "Lauku atbalsta dienesta publiskie pārskati 2004. …2009" ("Public Reports of the Agricultural Support Service", Ministry of Agriculture) [11]. The total amount of fuel consumed in agriculture can be found in the database "Energetics" of the Central Statistical Board [12]. It is partly characterised also by the data in "Gada ziņojumi 2000. …2009" (the Annual Reports of the Ministry of Agriculture [15] on the payment of the excise tax for the actual area of land used to produce agricultural products).

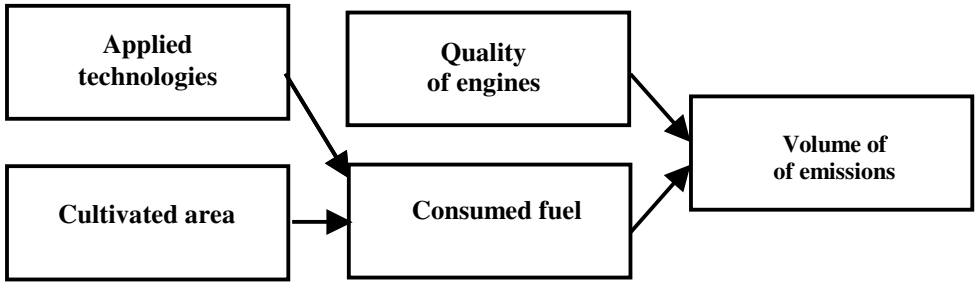

Fig. 1. **Factors affecting the volume of polluting emissions in the air**

Processing of the data obtained from the previously mentioned sources by methods of mathematical statistics, their analysis, comparison and interpretation are the basic methods among the mentioned ones used to prepare the material discussed further.

Results and discussion

One can consider that modernisation of machines and technologies for field crop cultivation in Latvia started since the year 1996 because in this year state subsidies were granted to agriculture for the first time and therefore a gradual increase ensued in the purchase of machines produced in the EU, including tractors. In the period before 1996 the agricultural farms bought tractors which were made for the most part in the CIS countries, their purchase decreasing annually from 4652 tractors in the year 1989 to 352 tractors in 1996. Since 1997 there were acquired from 500 to 1600 new tractors every year, and it was in this period that a gradual increase started in the purchase of tractors made in

the EU. However, approximately till 2006 more than a half of the total number of the purchased tractors were tractors of the MTZ brand.

The allowed volume of pollutant emissions in the air for the engines of tractors and agricultural self-propelled machines (further in the text – tractor engines) is regulated in the country by the Directive 97/68/EU [5] and Regulations No.1047 of the Cabinet of Ministers of 27.12.2006 [16] which provide for the allowed volume, $g \cdot kWh^{-1}$, of the four main components of emissions: carbon oxide (CO), hydrocarbons (HC), nitrogen oxides (NO_X), and particulates (PT) in the tractor emissions (exhaust gases). Consequently, the volume of emissions of a tractor engine which is ready for service will depend on the specific fuel consumption of the engine, $g \cdot kWh^{-1}$, and the amount of fuel consumed by the tractor. The normative documents [5; 16] group engines by their capacities, setting lower allowed norms of emissions for the engines of higher capacities, this directive being altered several times in the course of time, thus decreasing the allowed volume of emissions in approximately every four years (periods) for the engines of all capacity groups [6; 7; 8]. The data on the allowed volumes of emissions in a corresponding period by their components and, in total, for two most popular groups of engines are summarised in Tables 1 and 2.

Table 1

The allowed volumes of emissions ($g \cdot kWh^{-1}$) for the tractor engines with a power of 75<*P*<130 kW by periods

Period/number of components	CO	HC	NOx	PT	Total
Since July 1, 1998	5.0	1.3	9.2	0.7	16.2
Since January 1, 2002	5.0	1.0	6.0	0.3	12.3
Since January 1, 2006	5.0	HC+NOx total 4.0		0.3	9.3

Table 2

The allowed volumes of emissions ($g \cdot kWh^{-1}$) for the tractor engines with a power of 37<*P*<75 kW by periods

Period/number of components	CO	HC	NOx	PT	Total
Since July 1, 1998	6.5	1.3	9.2	0.85	17.85
Since January 1, 2002	5.0	1.3	7.0	0.40	13.70
Since January 1, 2007	5.0	HC+NOx total 4.7		0.40	10.10

A volume of total emissions, similar to the estimated one in Tables 1 and 2, is indicated also by other authors [17]. The numerical values of the emissions given in the column "Total" of these tables allow calculation of the volume of emissions which arise from an engine of the corresponding group during the period fixed by the normative documents in a definite period, consuming one ton of fuel. It is assumed for approximate calculation that all the engines have the same specific fuel consumption of 205 $g \cdot kWh^{-1}$. The results of the calculations are shown in Table 3. In the following calculations it is assumed that all the tractors made in the EU and acquired after the year 1998 belong to the capacity group of 75<*P*<130 kW, those produced in the CIS countries belong to the capacity group of 37<*P*<75 kW.

Table3

The volumes of emissions ($kg \cdot t^{-1}$ of fuel) for the tractor engines of the most popular capacity groups by periods

Period	Volume of emissions 75<*P*<130 kW	Volume of emissions 37<*P*<75 k
Since July 1, 1998	79.0	87.0
Since January 1, 2003	60.0	66.8
Since January 1, 2007	45.4	49.3

In order to characterise the variations in the volume of emissions in a longer, for example, a ten-year period, it is necessary to calculate the annual volume of emissions from one tractor produced in

different periods taking into consideration the allowed volume of emissions set for each period and the amount of fuel consumed by the tractor in a year. To determine the amount of fuel consumed by the tractor during a year, the following assumptions were made: for approximate calculations it was assumed that the total fuel consumption by the tractor constitutes 85 % of the fuel consumed in agriculture, of which in the year 2009 the tractors purchased after the year 1998 consumed 85 %.

On the basis of these assumptions and the data found in the sources [12] and [14] it was calculated that one tractor purchased after the year 1998 consumed, on the average, 7.7 t of fuel a year, which, in its turn, allows calculating the average volume of yearly emissions from one tractor produced in different periods. The results of the calculations are indicated in Table 4.

Table 4

The volume of emissions from one tractor produced in different periods (kg·year^{-1})

Period/Tractors	Produced in the EU	Produced in the CIS
Since July 1, 1998	608.3	-
Since January 1, 2003	462.0	669.9
Since January 1, 2007	349.6	514.4

As it is evident, at the same fuel consumption, the volume of emissions from a tractor produced in each successive period in contrast to the previous year decreased approximately by 25 %.

The reason for the differences in the volumes of emissions from the tractors produced in the EU and the CIS countries is their inclusion in different capacity groups with a different allowed volume of emissions, as well as the elasticity system which is allowed by the Directive [5] and the Regulations of the Cabinet of Ministers [16], and made use of by the providers of these tractors. It provides a possibility for the producers of engines between two successive periods of setting limit values for emissions to offer a limited number of engines on the market that comply with the limit value fixed for the previous period, and the providers make wide use of this opportunity. Therefore, it is assumed that the volumes of emissions from the tractors made in the CIS countries agree with the limit values set for the previous period of time.

However, in order to calculate the decrease in the tractor emissions in absolute figures by applying the data from Table 4 and comparing, for instance, the volume of emissions in the years 1998 and 2009, there are several debatable methodological issues:

- one should know the allowed volume of emissions for the tractors made in the CIS before 1998 the specific weight of which within the total amount of agricultural operations at the beginning of this period was considerable;
- one should specify the consumption of fuel between the capacity groups of tractors at the beginning and at the end of the period discussed, and between agriculture and forestry because in [12] this has been indicated as common for the both branches mentioned;
- one should specify the issue about the number of tractors used in production which are made in the CIS countries before 1998 during the periods mentioned in the tables.

Conclusions

1. Exhaust emissions, or pollutants, from tractors have adverse effect on the environment and human health.
2. The level of emissions from the engines of self-propelled agricultural machines, including tractors is being gradually limited. It is regulated by both: the Directive 97/68/EC with its amended Directives on the European Union level, and by the Regulations of the Cabinet of Ministers on the Latvian level.
3. A methodological approach is developed as a result of investigations how to estimate the volume of pollutants emitted by the tractor engine depending on the year when the tractor was produced, and the amount of the consumed fuel.
4. Approximated (tentative) calculations show that at the same fuel consumption rate the volume of emissions from a tractor produced in each successive period decreases approximately by 25 % in contrast to a tractor produced in the previous period.

5. Investigations should be continued in order to estimate the total variations in the pollutant emissions in the air and their trends in a long-term, for instance, a ten-year period on the basis of the developed and offered approach.

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