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METHODOLOGY FOR THE ESTIMATION OF CHANGES IN THE AMOUNT OF POLLUTING EMISSIONS CREATED BY THE FLEET OF TRACTORS

Summary

Considerable financial means have been invested during the last decade in modernization of agricultural machinery, including purchase of new tractors. As the corresponding EU directive sets gradual, by periods, reduction of the pollutants in the air for the new tractors and the number of such tractors with the specific fuel consumption are known, a methodological approach was offered in 2011 for the estimation of the variations in the amount of polluting emissions in the air created by the new tractors in a longer period of time [1]. However, in order to evaluate the impact of modernisation of the entire fleet of tractors upon the pollution variations in a longer period of time, for instance, by comparing the year 1996 or 2000, and 2010, one should know the characteristics of the pollution caused by the tractors produced in the former Commonwealth of Independent Countries (further – the CIS countries) which performed most of the farming operations at the beginning of the period mentioned. As parametrs for the estimation of the summary pollution in tons per year during the selected years were set the ratio of fuel consumption between the "new" and the "old" tractors, as well as distribution of the fuel consumption between agriculture and forestry because it is indicated in statistical reports as a common parameter. Distribution of fuel consumption was estimated also between tractors produced in the EU and the CIS countries. After the motivation of these assumptions an estimate was made of the summary air pollution emitted by the fleet of tractors in the years 1996, 2000 and 2010. The obtained results were evaluated in a brief discussion and a direction was outlined for further investigations.
***Key words**: tractors; pollutants; polluting emissions; estimation; methods*

1. Introduction

The summary amount of emission of the pollutants in the air created by tractors depends on a series of factors – the amount of the consumed fuel, the cultivated area and the applied technologies, the quality of the tractor engines and their technical condition. In contrast to the year 2000, in the year 2010 the amount of the fuel consumed in agriculture and forestry had increased 1.5 times [2]; consequently the amount of the polluting emissions in the air could have grown too. However, 8275 new tractors [3] were purchased during this period the specific fuel consumption of which and the specific amount of emissions in the air is much lower. A methodology for the estimation of the summary emissions caused by the new tractors is laid out in the previous publication by the authors of this article [1]. It is based on the compliance of the emissions created by the new tractors with a level set for each period by the EU Directive [4]. Yet an issue has not been studied till now about the amount of the pollutants emitted by the used tractors. As it is well-known, before 1995 tractors were brought into Latvia that were produced mainly in the CIS countries for which no norms of polluting emissions existed in that time and which were intensively used then and a part of them are being used even now. Since 1996 the purchase of tractors produced in the EU countries and the amount of the work performed by them are gradually increasing, and the norms of the polluting emissions are applied also to the tractors made in the CIS countries. The purpose of this article is to offer a methodology for the estimation of the summary amount of polluting emissions in the air created by a fleet of agricultural tractors during a longer period of time. By comparing the summary amount of the polluting emissions created, for instance, in 2000 and in 2010, within a context of the modernisation indicators of the fleet of tractors it will be possible to evaluate the impact of modernisation upon the variations in the amount of emissions during a ten-year period.

2. Materials and methods

Several methodological issues have to be solved in order to determine the summary amount of pollutants created by a fleet of tractors in a year.

The most important issue is the amount of the polluting emissions caused by the tractors brought in from the CIS countries before the year 1996. In contrast to the tractors imported in Latvia now, the norms of their emissions were not indicated in the normative documents; therefore data of the measurements carried out during the inspection of real tractors could be used. Such measurements were carried out in 2008-2010 by the State Technical Inspection Agency in cooperation with the Certification and Testing Centre which inspected 1000 tractors within the framework of a financed project of the EEZ financial instrument. The measurements were made in conformity with the test envisaged by the Directive 77/537 EEC of the European Council [5] in the free acceleration mode, determining the light absorption coefficient of emissions, or fuel gases, which characterises the amount of soot, or solid particles (designated in the directives as – PT). A similar method is applied during the annual technical inspection in order to check the amount of the polluting substances emitted in the air by the diesel engines of automobiles. Only here more indicators are registered. The results of the measurements are grouped by the brands of tractors, and the indicators of the most widespread brands, in their turn, are divided into intervals according to their age, including 5 years into one interval. Further, the average light absorption coefficient of emissions, or fuel gases, is calculated for each interval. After that, considering the number of tractors of each brand in the corresponding interval of years, the average light absorption coefficient of the fuel gases measured is calculated, which is the value characterising the average amount of the pollutants emitted in the air by the tractors of the respective age interval. The shortcoming of the methodology is that the variations in the summary amount of emissions are

evaluated only by one indicator – the average amount of soot, or solid particles PT. It would be more correct to estimate these variations by four indicators set by the Directive [4] – the amount of carbon oxide (CO), hydrocarbons (HC), nitrogen oxides (NOX) and solid particles (PT). However, such data are available in the country only for a few tractors.

One should also specify the annual amount of diesel fuel consumed in forestry as the materials of the Central Statistical Board [4] indicate only the total amount of fuel annually consumed in agriculture and forestry. Since almost all the amount of fuel used in forestry is consumed in logging, data should be applied for the calculation of the fuel consumption (in l/m3) in logging by means of a harvester and a forwarder, or only a forwarder. These data can be found in the normative documents of the joint-stock company "Latvijas Valsts Meži" [6] but the data about the logging extent in a particular year – in the materials of the Central Statistical Board [7]. The difference between the entire amount and the amount consumed in logging will be the amount of fuel consumed in agriculture.

Besides, it is necessary to specify the number of tractors operating in the respective year, separating the tractors imported from the CIS and from the EU, and their correspondence to the age groups mentioned above. These data can be found in the materials of the State Technical Inspection Agency [3]. In further calculations, as in the other materials [8], it is assumed that only those tractors take part in the production of agricultural products which are in good technical order.

The next issue to be clarified is an issue about the intensity of using tractors from different age groups, which can be specified by the amount of the consumed fuel. This issue has been studied by Estonian scientists [9] for several years, who have analysed data about the fuel consumption on the farms of approximately 400 tractors from different age groups. They have found out the distribution of the fuel consumption for four age groups of tractors: 0-5 years, 5-10 years, 10-15 years, and more than 15 years. The distribution described in the publication is used in further calculations of this research.

Processing, analysis and interpretation of the data obtained from the sources mentioned by means of the methods of mathematical statistics are the basic methods used in the preparation of the material expounded further.

3. Results and discussion

In order to determine the light absorption coefficient of the emissions for the tractors imported from the CIS countries till 1996, data were used obtained during the tractor inspection carried out by the State Technical Inspection Agency in cooperation with the Certification and Testing Centre. 639 emission measurements were selected from the data volume (approximately 1000 tractors) comprising eight most popular brands of tractors made in the CIS countries. The distribution of measurements by the brands of tractors is shown in Table 1.

As it is evident, 74% of the inspected tractors are of the MTZ brand, which approximately corresponds to the data of the State Technical Inspection Agency about the distribution of various brands of tractors in the country. Consequently, the data selection according to this indicator is representative.

The light absorption coefficient, which characterises the amount of the allowed emissions for various brands of tractors mentioned in Table 1 differ a little, and it is within the limits 2.1 – 2.8; for the tractors of the MTZ brand it can be assumed as 2.2 [5]. Since the ratio of the tractors of these brands in the selection is 74%, it is assumed for further calculations that the coefficient which characterises the average allowed amount of emissions for all the inspected brands of tractors is 2.25.

The obtained measurements can be grouped by various features – the age of the tractors, their brand, capacity, technical condition, mass. As the purpose of the article is to clarify variations in the emissions in the air of the entire fleet of tractors during a longer period of time, the most important factor is their grouping by age, including into the selected age groups the average coefficients that characterise the emissions of the tractors of all the age groups independent of the brand. Such a grouping is shown in Table 2.

The data of the table convince that the coefficient characterising the amount of emissions grows with the increase in the service life of tractors, and it exceeds the allowed norm for the tractors which are already 6-10 years old. The number of measurements in all the age groups, except the first one, is sufficient.

Tractors have been grouped also by the, as well as by the existence of technical inspection. In the grouping by engine capacity the tractors are divided into groups 1-50, 51-100 HP, etc. However, this grouping does not show a coefficient characterising the amount of emissions in a group of a particular capacity which is essentially different from the other groups. In the grouping according to the existence of technical inspection it was cleared up that approximately 18% of the inspected tractors have not undergone technical inspection. Yet in this grouping no essential differences of the coefficient characterising the amount of emissions created by tractors with and without technical inspection were found either.

Table 1. Distribution of the measurements of emissions by the brands of tractors

Brand	MTZ	T-40 T-40A	T-150 T-150K	T-25	JUMZ	K-700 K-701	T-16	DT-75
Number of measurements	474	46	43	26	24	12	8	6

Table 2. The average coefficient that characterizes the amount of emissions depending on the age of the tractors

Age group, years	1-5	6-10	11-15	16-20	21-30	More than 30
Number of measurements	4	86	95	43	336	75
Average coefficient	1.74	2.47	2.90	3.83	4.23	5.43

As already mentioned, the materials of the Central Statistical Board indicate the total annual fuel consumption in forestry and agriculture. As almost all the amount of fuel in forestry is used up in logging, then it mainly depends on the logging extent in a year, the kind of the forestry operation and the specific fuel consumption in tree felling with a harvester and transportation with a forwarder. Using the data from source [6] and [7], it was calculated that 23–27% of the total fuel consumption in agriculture and forestry is consumed just in forestry. It was assumed in further calculation that 90% of the fuel consumed in agriculture is used up by tractors, 10% - for drying kilns, transport and other needs, and in this case in the year 1996 tractors consumed 52.4 thousand tons of fuel, in 2000 – 40.5 thousand tons, and in 2010 – 66.2 thousand tons of fuel.

As it is well-known, the amount of the polluting emissions in the air is directly proportional to the amount of the consumed fuel. However, as evident in Table 2, it is different for the tractors of various age groups produced in the CIS countries and also for the tractors made in EU countries [1, 4]. In order to judge about the summary amount of the pollutants in the air created by the fleet of tractors in different years, one has to find out the distribution of the fuel consumption among the tractors of various age groups as well as between the tractors produced in the CIS and the EU countries because the levels of emissions are different. As already mentioned, a serious research of the fuel consumption by the tractors of diverse age groups has been carried out by Estonian scientists J. Olt, Y. Traat, A. Kuut [9] who have established that on the farms approximately 48% of the total tractor fuel consumption are used up by the tractors which are 1-5 years old, 35% - by the tractors which are 6-10 years old, 11% - by the tractors which are 11-15 years old, and 6% - by the tractors which are more than 15 years. Consequently, about 94% of the entire fuel consumed by the tractors is used up by the tractors which are less than 15 years old. Such a distribution of the fuel consumption among the tractors of various age groups is applied also in the following calculations. Yet there are no investigations about the distribution of the fuel consumption between the tractors produced in the CIS and the EU countries. Therefore, to clarify it, Table 3 is created where the tractors are divided into three age groups which, as mentioned before, consume approximately 94% of the entire fuel of the fleet. It was assumed for the data analysis of Table 3, as well as data [8] about the summary capacity of the tractors made in the CIS and the EU that the distribution of the fuel consumption between the tractors produced in the CIS and the EU countries is the following: 97% and 3% in the year 1996, 85% and 15% – in 2000, 20 % and 80% – in 2010.

Table 3. Distribution of the tractors produced in the CIS and the EU countries according to age groups

Year	1996		2000		2010	
Tractors produced in	CIS	EU	CIS	EU	CIS	EU
Total number	46027	137	39974	642	29844	3528
Less than 5 years old	7459	96	2315	551	768	2112
Less than 10 years old	29700		6432	46	1659	1207
Less than 15 years old	6900		15350		2410	101

Further, using the data from Tables 2 and 3, the abovementioned data about the distribution of the fuel consumption by years between the tractors made in the CIS and the EU countries, as well as the data about the tractors of various age groups [3] and the amount of emissions presented in Table 3 per kg/t^{-1} of fuel given in the authors' publication of the previous year [1], one can calculate the summary amount of the polluting emissions in the air in the years 1996, 2000 and 2010. The obtained results are: in 1996 the summary amount of the polluting emissions in the air created by agricultural tractors was 6735 t, in 2000 – 5270 t, in 2010 – 3822 t.

Consequently, by applying the methodology offered by the authors, it was estimated that the summary amount of the polluting emissions in the air created by agricultural tractors after the modernisation of the fleet of tractors had diminished in the year 2000 by approximately 22% in contrast to the year 1996, but in 2010 – by about 47%. The use of this methodology makes it possible to calculate variations in the amount of the polluting emissions in the air also in relation to the other years.

These results should be regarded as tentative, and they have to be specified during the following investigations because, as it is mentioned in the Introduction, the methodology is based not only on impartial data but also on several experts' assumptions. One of the issues to be specified in the future is about the amount of emissions created by the tractors produced in the EU countries. As mentioned, it is not a definite survey of tractors as for the tractors made in the CIS countries but accepted as corresponding to the level set by the EU Directive for each period. Debatable is also the issue about the comparability of the amounts of the polluting substances in the air as they are determined using different measuring methods. The distribution of the fuel consumption between the tractors produced in the CIS and the EU countries is based on an assumption made by experts as a result of the data analysis, too.

4. Conclusion

1. A tentative methodology is offered for the estimation of the summary amount of polluting emissions in the air created by a fleet of agricultural tractors in different years, thus providing a possibility to evaluate the impact of its modernisation upon the amount of the pollutants.
2. By applying this methodology it was estimated that the summary amount of the polluting emissions in the air created by agricultural tractors after the modernisation of the fleet of tractors had diminished in the year 2000 by approximately 22% in contrast to the year 1996, but in 2010 – by about 47%.
3. Several methodological aspects have to be specified in further investigations which would allow estimation of the diminished emissions in greater detail and with greater credibility.

5. References

[1] D. Viesturs, N. Kopiks, L. Melece, I. Zakis. Methodological aspects for the estimation of the impact of modernisation of the fleet of tractors upon the polluting emissions in the air. Proceedings of 10th International Scientific Conference "Engineering for Rural Development", Jelgava, 2011, pp. 201-205.

[2] Enerģētika // [online] [6.02.2012]. Available at: //http/ www.csb.lv/ Enerģētika/ ENG 08 Energobilance / (NACE 2..redakcijā). (Energetics/ ENG 08 Energy Balance (MACE 2..editors) [in Latvian].

[3] Valsts tehniskās uzraudzības aģentūras pārskati 1996...2010.g. (Reviews of the State Technical Control Agency 1996…2010), Rīga, Zemkopības ministrija. [in Latvian].
[4] Directive 97/68/EC of the European Parliament and of the Council of 16 December 1997 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, Official Journal of the European Communities, L 59, 27.2.98, pp. 1-85.
[5] Council Directive 77/537/EEC of 28 June 1977 on the approximation of the laws of the Member States relating to the measures to be taken against the emission of pollutants from diesel engines for use in wheeled agricultural or forestry tractors, pp. 1-23.
[6] Degvielas patēriņa normas mežizstrādē. A.s."Latvijas valsts meži" normatīvais documents, 2008., 5.lpp. (The norms of fuel consumption in logging. A normative document of the Joint-stock company "Latvijas valsts meži", 2008, 5 pp.) [in Latvian].
[7] Mežsaimniecība (Forestry) // [online] [17.02.2012]. Available at: //http/ www.csb.lv/ Mežsaimniecība, MSG02. Mežizstrādes apjomi sadalījumā pa īpašuma formām (Forestry, MSG02. The logging extent by the forms of property) [in Latvian].
[8] Semjons Ivanovs et.a..: Contribution of the Resesrch Institute of Agricultural Machinery during 50 Years of its Existence. 9th International Scientific Conference „Engineering for Rural Development. Procedings, Volume 9. May 27-28, 2010. Jelgava. pp. 13-24.
[9] Jyri Olt, Ylo Traat, Arne Kuut. Maintenance costs of intensively used self-propelled machines in agricultural companies. Proceedings of 9th International Scientific Conference "Engineering for Rural Development", Jelgava, 2010, pp. 42-48.