Analyzing the production of limited harmful substances from mobile sources of energy in agriculture

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Abstract: An expert estimate of the weight of emissions produced in agriculture has been up to now made only through a final counting to the total REZZO 4 emission balance in the category of "other mobile sources" The existing situation is however unbearable since a proper methodology to determine the production of emissions in agriculture, i.e. in the department with a considerable consumption of fossil fuels, is still missing. The solution consists in a more precise specification of the weight of generated limited pollutants (CO, NO_x, SO_2, PM and VOC including CO_2) in the department of agriculture on the basis of the measured annual consumption of fuels in agriculture and with using the emission factors of fuels. Calculated results are compared with the original values finally counted for the REZZO 4 category of "other mobile sources" in 2000 and 2001 (Adamec 2002; Adamec *et el.* 2003). The calculation revealed that the weight production of individual pollutants in 2000 and 2001 reached only 28% and 27% for CO, 52% and 50% for NO_x, 69% and 66% for SO_2, 87% and 83% for PM, and 26% and 24% for VOC of the original estimates with final counts and was therefore much lower. The share of agriculture in the weight production of emissions from mobile sources in 2000 and 2001 was 3.1% and 3.1% for CO, 11.5% and 11.5% for NO_x, 19.8% and 18.8% for SO_2, 38.3% and 34.6% for PM, and 3.5% and 3.6% for VOC. The development of weight production for individual pollutants in the period from 1995–2005 is expressed by means of regression equations. Coefficients of reliability indicate that the measure of reliability of the interval determined by calculation is much higher than that of the reliability interval determined by values estimated through final counting that appear incidental. There are increasing efforts today focused on the replacement of diesel oil as a traditional fossil fuel in agriculture with biodiesel oil as a more environment-friendly fuel. The second part of results includes a monitoring of the impact of biodiesel oil emissions in cases where diesel oil was replaced by this ecological fuel in agriculture in the period from 2000–2005. It follows from the analysis that the weight production of pollutants in 2000–2005 would have been reduced by 4% in CO, by 28% in SO_2, by 52% in PM and by 4% in VOC while an increase by 20% and 32% would have been recorded in CO_2 and NO_x, respectively. Regression equations are used to express the development of the weight production of individual diesel oil and biodiesel oil pollutants in the period from 2000–2005. Reliability coefficients that are of constant character indicate that the development of the weight of pollutants from diesel oil replicates the development of biodiesel oil pollutants. The significance of achieved results consists in the provision of a more accurate general balance of emissions from one of so called other mobile sources in Czech Republic (apart from the department of transport), thus contributing among other things to a more accurate expression of the total weight of emission production within REZZO 4.

Keywords: diesel oil; biodiesel oil; emission factor; standard weight of fuel oil; area size under crops; limited harmful substance; pollutant; emission

Apart from mobile power supply sources in the department of transport the balance of emissions from mobile sources is also contributed to by the department of agriculture with the traditional diesel oil and the recently preferred biodiesel fuel.

Emission limits of mobile power sources are specified in the international regulation Directive 96/61/EC of the European Parliament and of the Council as amended, and are therefore in harmony with EU limits. Other emitted pollutants such as PAH or benzene are not covered by legislation at the present time.

Current methodological procedures to determine the amount of produced emissions (e.g. from traffic) are based on fuel sales records (Dufek 2001). However, as the fuel consumption in agriculture is not monitored as a separate item (Syrový 2003), the procedures cannot be used to calculate the amount of emissions generated by power supply sources in agriculture.

The calculation of emissions from agricultural mobile power sources can be successfully made on the basis of diesel oil consumption normatives for individual agricultural manufacturing technologies in plant and animal production, possibly also in some other branches of agricultural production that may be of statistic significance. Normative calculations of the weight of consumed diesel oil were stipulated for conditions of companies equipped with appropriate machines of parameters corresponding to requirements of the year 2000.

The calculation method takes into account only the weight of emissions generated directly from the operation of mobile power supply sources not considering emissions generated by other sources – e.g. from the generation of electric energy consumed by electric appliances used in agriculture or emissions produced by biological processes.

MATERIAL AND METHODS

The method is constructed in such a way that annual weight production of emissions can be calculated from available data that are monitored every year and officially published such as Statistic Annual Report, Green Report, etc.

For the purposes of calculating the annual consumption of diesel oil with the aim to specify the mass of annual production of emissions the weight of diesel oil consumed in agriculture was divided into four consumer branches that can express year-on-year changes in diesel oil consumption in the simplest and at the same time most flexible and perspective way:
– Plant Production (PP)
– Animal Production (AP)
– Technology Transport and material handling in agriculture (TT)
– Hobby Activities of the population (H)

For the purposes or practical calculation and further statistic processing of results the relatively heterogeneous and unstable structure of monitored crops had to be cumulated into fewer items whose data are available every year. A foundation of this simplified structure of monitored crops became the structure published in the Statistic Annual Reports for 2000–2005.

Cultivated crops were classified into thirteen groups by common features and similar growing technologies. Weight normatives of consumed diesel oil defined for each partial crop in respective groups were converted to a common group of crops according to the size of areas under crops of individual subgroups in the group for the period from 2000–2005 (Kavka 2000a, b). These groups of crops provide a true picture of reality in the Czech Republic.

Similarly, the item of "animal production" had to be cumulated into less groups, too. The entire scale of reared animals was put together into three animal groups of beef cattle, pigs and sheep. Partial normatives of diesel oil consumption for each individual category of animals were converted to a cumulated normative for the whole group of animals (according to the representation of individual species in the group).

Attention is paid mainly to the standard method of animal rearing that occurs most in the Czech Republic. The number of animals in all groups for each year can be easily obtained from the Statistic Annual Report.

The rearing of other monitored animal groups such as fowl, horses and other animal groups of lower statistic importance has no separate records on weight normatives of consumed diesel oil per head but diesel oil consumption in fully automated manufacturing technologies is rather included in the "technology transport and material handling". The weight of diesel oil consumed in small farms with mainly extensive method of production is included in the "hobby activities of the population".

Technology transport and material handling represent an important branch of diesel oil consumption in agricultural production.

The item contains the following categories:
– in-plant transportation over 3 km,
– inter-plant transportation,
– technology transport in animal production (groups "cattle", "pigs", and "sheep"),
– "fowl" category (as a fully automated technology of production),
– category of "other reared animals".

The share of this branch in total consumption in agriculture was expressed by a flat fuel weight per unit area of farmland.

Official statistics do not include surfaces on which crops are grown within the framework of so called "hobby activities of the population" such as the cultivation of cereals for domestic animals, small-scale growing of beetroot and potatoes, perennial fodder crops on arable land, grapevine, fruit trees, rearing of pigs and fowl for home consumption (not for sales). These activities have a long tradition in this country not for subsistence reasons but rather thanks to the habitual life style of older generations and thanks to the availability of farmland for these purposes in certain localities. Since the "hobby activities of the population" are represented mainly by extensive farming methods, they are not ruled by economic inputs as the large-scale production technologies. The consumption of diesel oil (fossil fuels) not being standardized for these technologies but rather minimized and replaced mainly by manual work, it is enough if the activities are taken into account as an expert estimate of their share in agricultural land. It is expected that the trend of these activities will be decreasing in the future.

Another important input in the calculation is the emission factor of fuel (diesel oil, biodiesel oil) for individual pollutants. The emission factors were obtained from the database of CDV Brno and represent the existing condition and composition of mobile power supply sources in the Czech Republic.

The method is useful namely for the determination of emission weights for individual pollutants on a national level and for their prognoses in time. However, it can be also used on a regional level to determine the emission weights of individual pollutants on a level of regions. What must be known as input data are sizes of areas under crops for the respective groups of crops, numbers of animals kept in the respective groups, size of farmland area in the given municipality.

The method of calculating emissions from agricultural technologies consists in:

(a) Determination of the weight of used fuels m_s (diesel and biodiesel oils) in the respective branches of consumption and in agriculture m_{sZ} for a year and for a period of *e* years

(b) Determination of the weight of individual pollutants m_{pi} emitted in the respective branches of consumption and in agriculture for a year and for a period of *e* years

ad (a) Establishing the weight of used fuel – m_s

The weight of fuels used in agriculture per year m_s is given by the sum of partial weights of diesel oil used in the individual branches according to Eq. (1) as follows:

$$m_s = m_{sPP} + m_{sAP} + m_{sTT} + m_{sH} \text{ (kg)} \qquad (1)$$

where:

m_{sPP} – weight of fuels used in Plant Production per year (kg)

m_{sAP} – weight of fuels used in Animal Production per year (kg)

m_{sTT} – weight of fuels used in Technology Transport and material handling per year (kg)

m_{sH} – weight of fuels used in Hobby Activities of the population per year (kg)

The weight of diesel oil used in Plant Production per year (m_{sPP}) will be established according to Eq. (2) as follows:

$$m_{sPP} = \sum_{i=1}^{n} S_i \times q_i \qquad \text{(kg)} \qquad (2)$$

where:

S_i – square area under the i^{th} crop (m^2)

q_i – normative weight of diesel oil for the square area under the i^{th} crop (kg/m^2)

The weight of diesel oil used in Animal Production (m_{sAP}) will be established according to Eq. (3) as follows:

$$m_{sAP} = \sum_{i=1}^{n} n_{iz} \times q_{iz} \qquad \text{(kg)} \qquad (3)$$

where:

n_{iz} – number of animals of the i^{th} category (heads)

q_{iz} – normative weight of diesel oil per animal of the i^{th} category (kg/head)

The weight of diesel oil used in Technology Transport and material handling (m_{sTT}) will be established according to Eq. (4) as follows:

$$m_{sTT} = S \times q_{TTi} \text{ (kg)} \qquad (4)$$

where:

S – farmland area in the given year (m^2)

q_{TTi} – normative weight of diesel oil per unit farmland area (kg/m^2)

The weight of diesel oil used in Hobby Activities of the population (m_{sH}) will be established according to Eq. (5) as follows:

$$m_{sH} = (m_{sPP} + m_{sAP} + m_{sTT}) \times q_{Hi} \text{ (kg)} \qquad (5)$$

where:

q_{Hi} – coefficient of diesel oil consumption in hobby activities per unit farmland area (kg/m^2)

ad (b) Establishing the weight of pollutant (harmful substance) – m_{pj}

The weight of the j^{th} pollutant m_{pj}, produced by agriculture per year will be established according to the following relation:

$$m_{pj} = m_{pjPP} + m_{pjAP} + m_{pjTT} + m_{pjH} \qquad \text{(kg)} \qquad (6)$$

The weight of the j^{th} pollutant m_{pj} for the respective consumer branch (PP, AP, TT, H) per year will be established according to Eq. (7)–(10) as follows:

$$m_{pjPP} = m_{sPP} \times Ef_j \text{ (kg)} \qquad (7)$$

$$m_{pjAP} = m_{sAP} \times Ef_j \text{ (kg)} \qquad (8)$$

$$m_{pjTT} = m_{sTT} \times Ef_j \text{ (kg)} \qquad (9)$$

$$m_{pjH} = m_{sH} \times Ef_j \text{ (kg)} \qquad (10)$$

where:

Ef_j – emission factor of the respective pollutant *i* (kg/kg)

The weight of pollutant m_{pje} emissions for the period of e years will be established according to Eq. (11) as follows:

$$m_{pje} = \sum_{i=1}^{e} m_{pj} \quad \text{(kg)} \qquad (11)$$

where:

e – years in the period of assessment

RESULTS AND DISCUSSION

Figures 1 through to 5 present a development of the weights of the respective limited pollutants defined in REZZO 4 with actual values measured by means of the above described method in 2000 and 2001 with the development of REZZO 4 values being monitored for the period from 1995 to 2001, and with the values

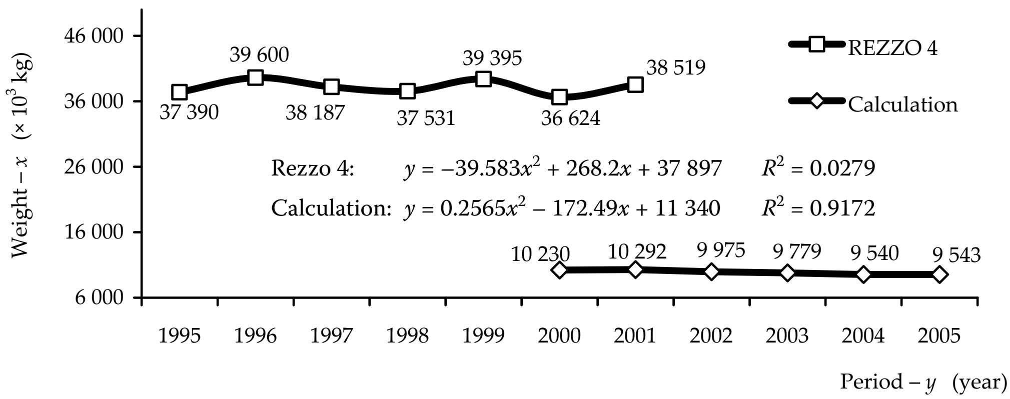

Figure 1. The comparison of CO pollutant weight established by the two methods in agriculture for the period from 1995–2005

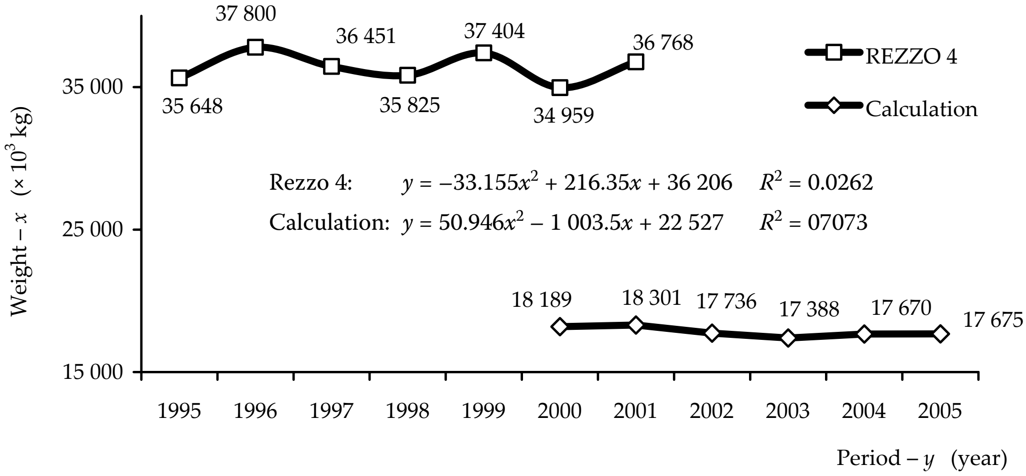

Figure 2. The comparison of NO_x pollutant weight established by the two methods in agriculture for the period from 1995–2005

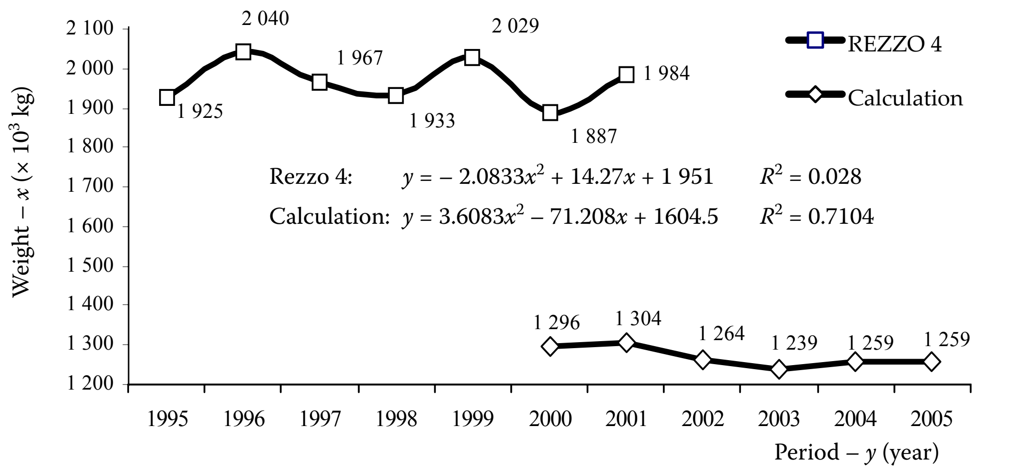

Figure 3. The comparison of SO_2 pollutant weight established by the two methods in agriculture in the period from 1995–2005

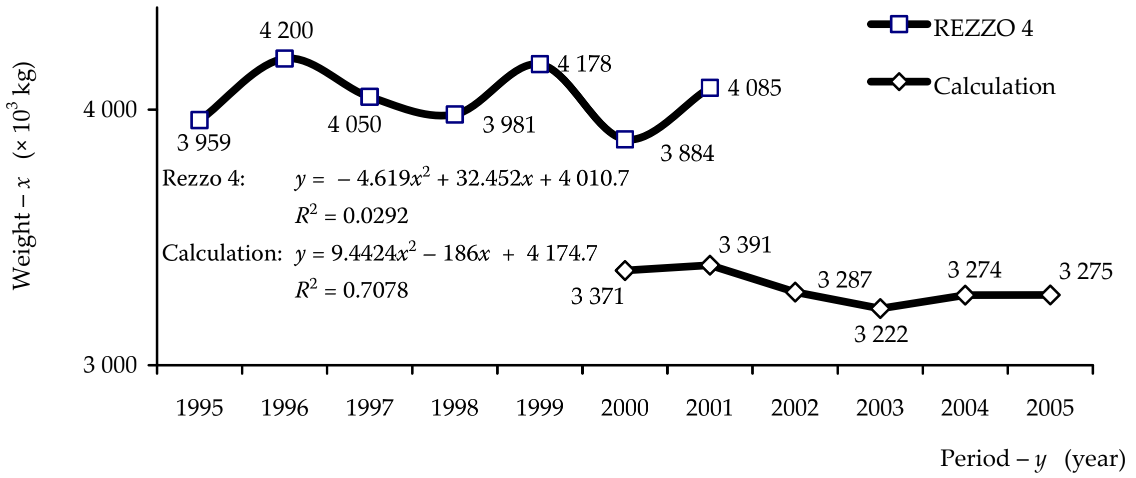

Figure 4. The comparison of PM pollutant weight established by the two methods in agriculture in the period from 1995–2005

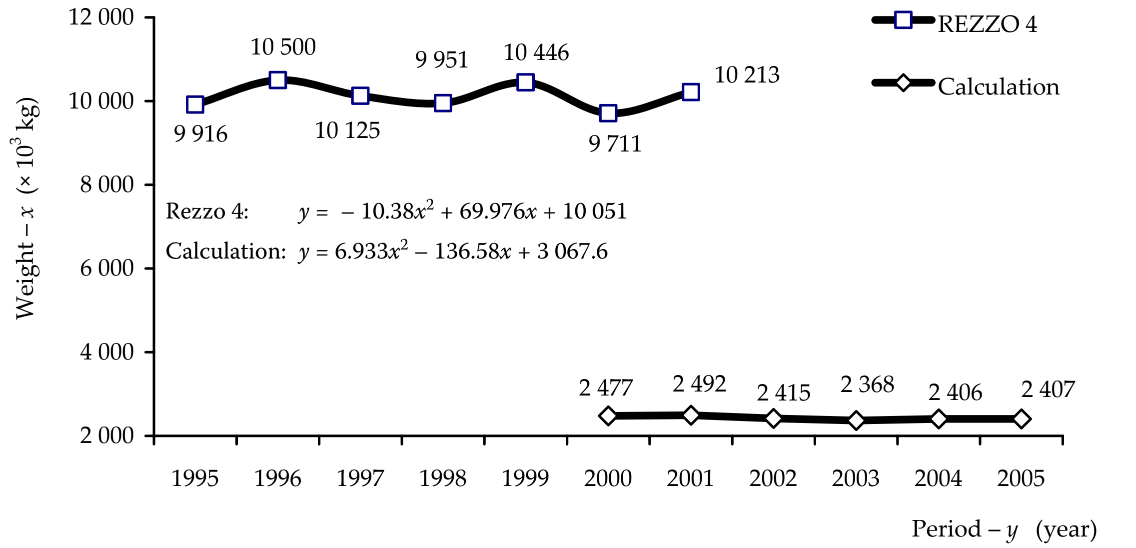

Figure 5. The comparison of VOC pollutant weight established by the two methods in agriculture in the period from 1995–2005

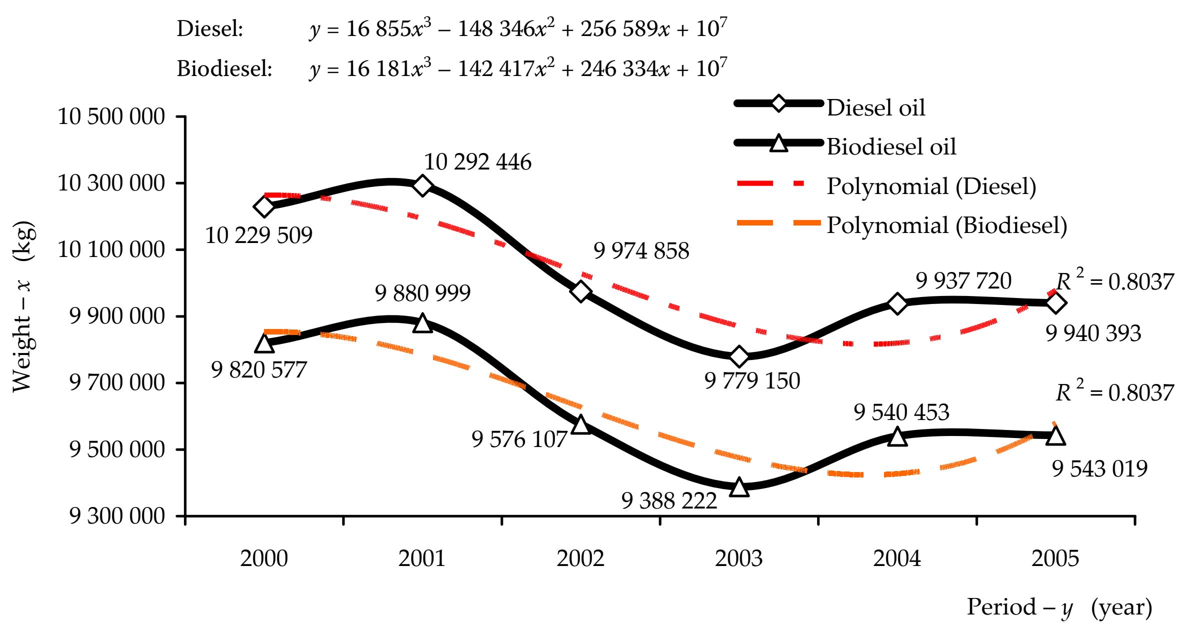

Figure 6. Weight development of CO produced in agriculture in the period from 2000–2005

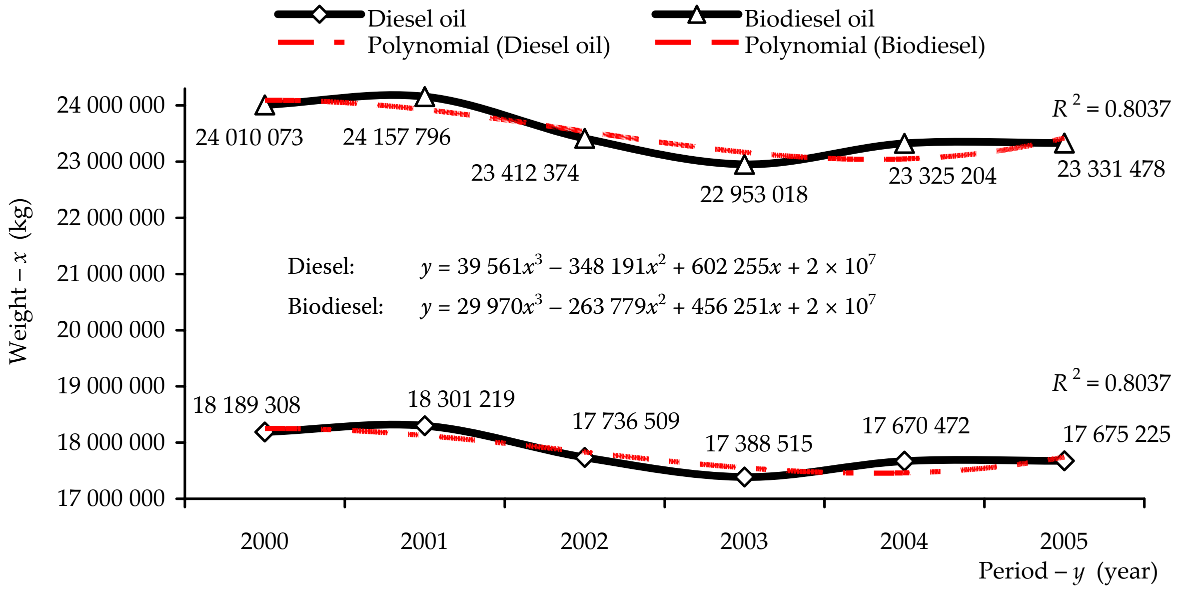

Figure 7. Weight development of NO_x produced in agriculture in the period from 2000–2005

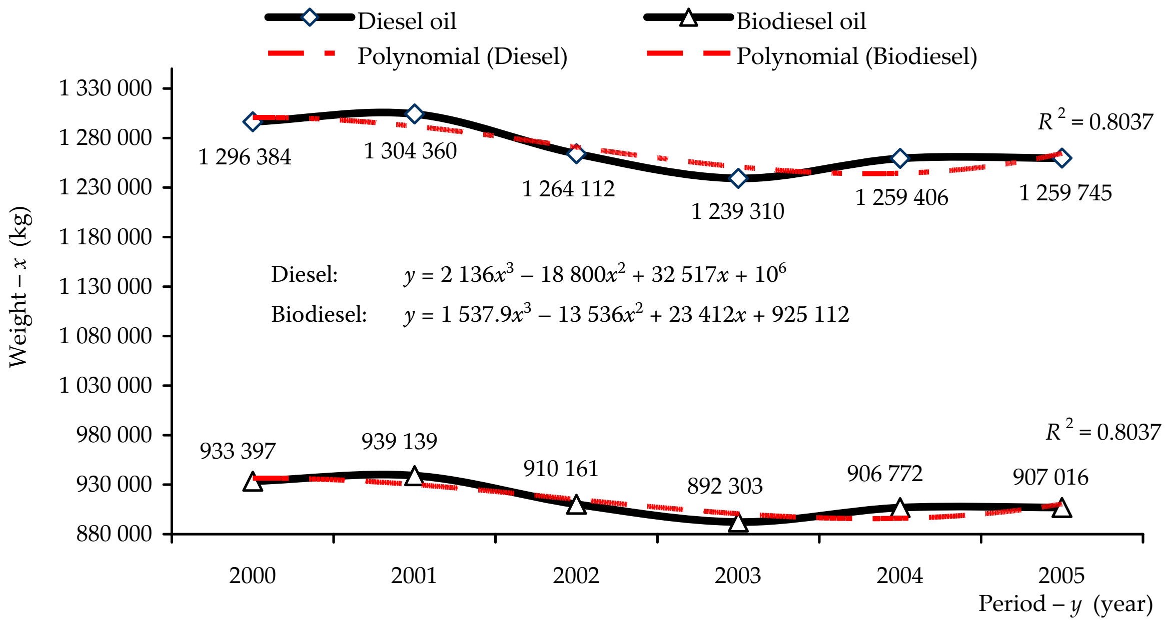

Figure 8. Weight development of SO_2 produced in agriculture in the period from 2000–2005

established through the calculation being presented for the period from 2000–2005. The developmental trends are described by the 2nd order regression polynomials with the coefficients of reliability.

As compared with the weights of individual pollutants finally counted to REZZO 4, the calculated weight of CO production in 2000 and 2001 amounted only to 28% and 27%, respectively (Figure 1), weight of NO_x production only to 52% and 50%, resp. (Figure 2), weight of SO_2 only to 69% and 66%, resp. (Figure 3), weight of PM only to 87% and 83%, resp. (Figure 4), and weight of VOC only to 26% and 24%, resp. (Figure 5).

It also follows from the calculations that the share of the department of agriculture in the weight production CO, NO_x, SO_2, PM and VOC from mobile sources in 2000 and 2001 was only 3.1%, 11.5%, 19.8% (18.8%), 38.3% (34.6%) and 3.5% (3.6%), respectively.

Based on the reliability coefficients whose values range for the values finally counted to REZZO 4 only between 0.0279 (CO and VOC) and 0.0292 (PM) it can be deduced that the original finally counted values are

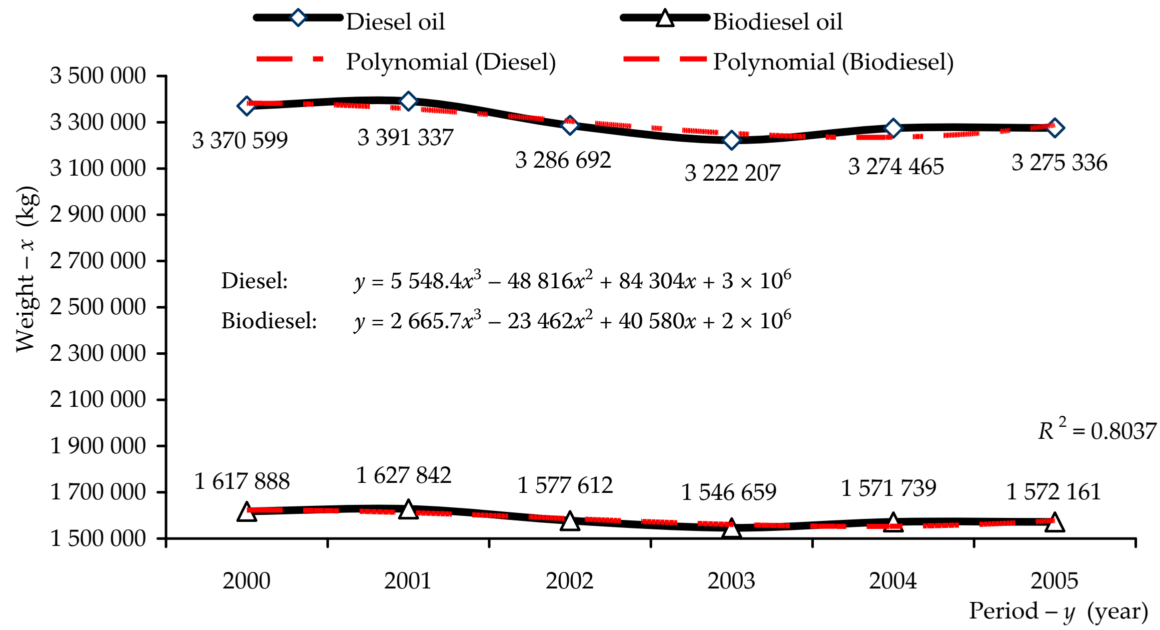

Figure 9. Weight development of PM produced in agriculture in the period from 2000–2005

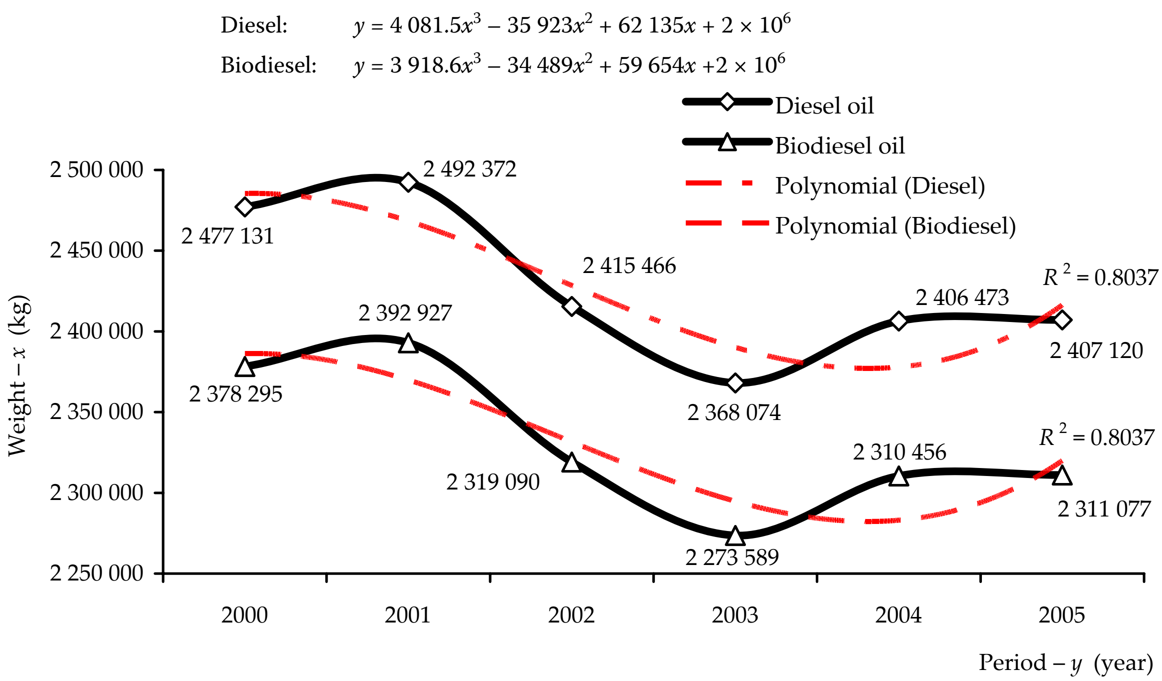

Figure 10. Weight development of VOC produced in agriculture in the period from 2000–2005

incidental and mutually independent while the reliability coefficients of calculated values that range from 0.707 (NO_x) to 0.917 (CO) point to a relatively significant dependence within the entire interval of reliability.

Figures 6–11 bring a comparison of the development of the weight of individual limited pollutants (including CO_2) produced from the classical fuel (diesel oil) with the development of the weights of these pollutants in the case of diesel oil substitution with the alternative fuel (biodiesel oil) for the period from 2000–2005. The regression equations expressed by 3rd order polynomials with the reliability coefficients of 0.8037 suggest a mutual correlation of values for the weights of individual pollutants produced from diesel oil and biodiesel oil.

The difference in the development of weights of the respective pollutants produced from diesel- and biodiesel oils in the period from 2000–2005 in the department of agriculture is presented both in aggregative annual values and as a course of their development that is described by polynomials of the 3rd order with the coefficient of reliability.

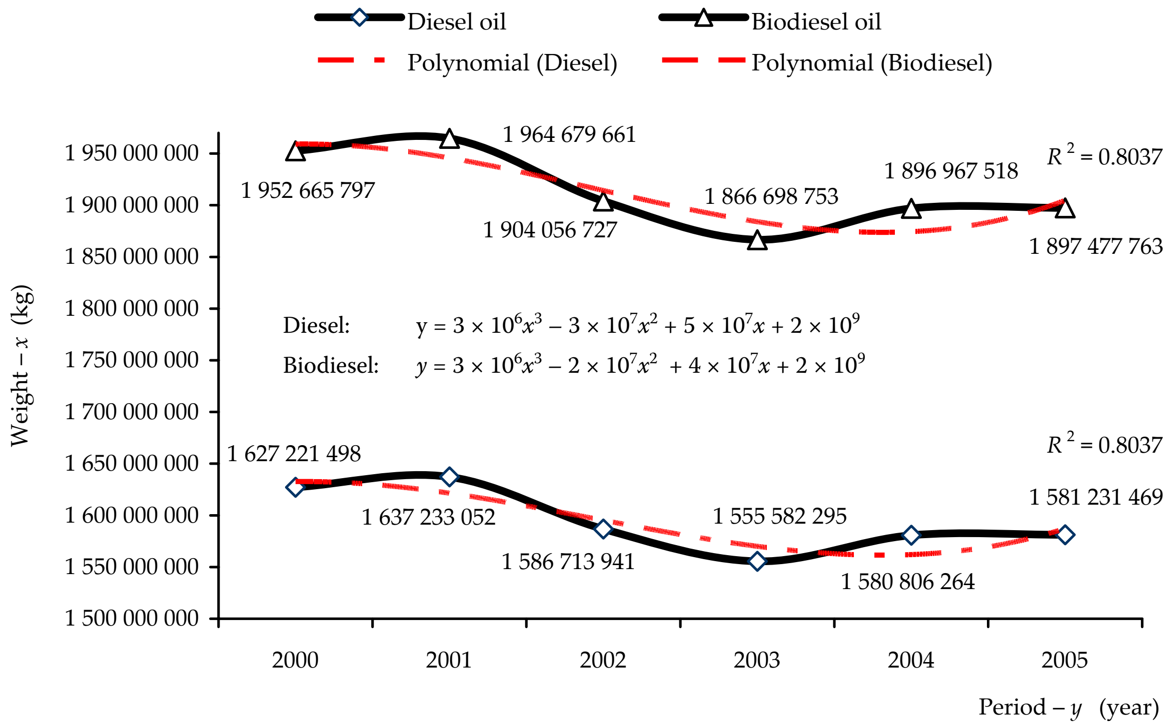

Figure 11. Weight development of CO_2 produced in agriculture in the period from 2000–2005

It follows from these dependences that a substitution of diesel oil with biodiesel fuel would result in a reduction of the weights of some pollutants: by 4% in CO (Figure 6), by 28% in SO_2 (Figure 8), by 52% in PM (Figure 9) and by 4% in VOC (Figure 10). However, the weight production of some other pollutants would increase: by 32% in NO_x (Figure 7) and by 20% in CO_2 (Figure 11).

The above facts show that the use of biodiesel fuel would reduce the weight share of emissions from mobile sources in the department of agriculture in the total REZZO 4 weight only in some of the monitored pollutants: CO from 3.1% to 2.9% in 2000 and from 3.1% to 3.0% in 2001, PM from 38.3% to 18.4% (from 34.6% to 16.6%), VOC from 3.5% to 3.3% (from 3.6% to 3.4%), and SO_2 from 19.8% to 14.3% (from 18.8% to 13.5%) while the share of weight production in NO_x would increase from 11.4% to 11.5% (from 11.2% to 11.5%).

Although the production of CO_2 has not been limited in the Czech Republic so far, the pollutant should be monitored as an important greenhouse gas for the creation of a whole spectrum of emissions. As compared with the use of classical diesel oil, its weight amount produced from biodiesel fuel in 2000–2005 would be increased by 20% (Figure 11).

The importance of the department of agriculture for air pollution standards defined by REZZO 1–4 is obviously lower than originally expected.

It also follows from the above results that the substitution of classical fossil fuel (diesel oil) by the alternative biodiesel fuel does not appear to be unambiguously in favour of the alternative with respect to the anticipated decrease in the production of emissions.

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Abstrakt

Homola J., Groda B. (2006): **Analýza produkce limitovaných škodlivin mobilními energetickými zdroji v zemědělství**. Res. Agr. Eng., **52**: 136–144.

Hmotnost emisí produkovaných v zemědělství je dosud pouze odborně odhadována dopočtem do celkové emisní bilance REZZO 4 v kategorii „ostatní mobilní zdroje". Tato situace je nadále neúnosná pro absenci metodiky vedoucí ke stanovení produkce emisí pro tak významný resort z hlediska spotřeby fosilních paliv, jakým zemědělství bezesporu je. Řešení spočívá především v upřesnění vyčíslování hmotnosti produkovaných limitovaných polutantů (CO, NO_x SO_2, PM a VOC včetně CO_2) v resortu zemědělství na základě zjištění roční spotřeby pohonných hmot v zemědělství a za použití emisních faktorů paliv. Vypočtené výsledky jsou porovnány s původními hodnotami dopočtenými pro kategorii REZZO 4 „ostatní mobilní zdroje" v roce 2000 a 2001. Výpočtem bylo zjištěno, že podíl hmotnostní produkce jednotlivých polutantů za roky 2000 a 2001 zjištěných výpočtem dosahuje jen 28 % a 27 % pro CO, 52 % a 50 % pro NO_x, 69 % a 66 % pro SO_2, 87 % a 83 % pro PM a 26 % a 24 % pro VOC původně dopočítávaných a jsou tedy výrazně menší. Podíl resortu zemědělství na hmotnostní produkci z mobilních zdrojů byl podle výpočtu v roce 2000 a 2001 pro CO 3,1 % a 3,1 %, pro NO_x 11,5 % a 11,5 %, pro SO_2 19,8 % a 18,8 %, pro PM 38,3 % a 34,6 % a pro VOC 3,5 % a 3,6 %. Pomoci regresních rovnic je vyjádřen vývoj hmotnosti produkce jednotlivých polutantů za období 1995–2005. Z koeficientů spolehlivosti vyplývá, že míra spolehlivosti intervalu stanoveného výpočtem je mnohem vyšší než intervalu spolehlivosti hodnot doposud dopočítávaných, které se jeví jako náhodné. V současnosti sílí snahy nahradit tradiční fosilní palivo v zemědělství – naftu motorovou „ekologičtějším" palivem – bionaftou. Druhou částí výsledků je zjištění emisního vlivu bionafty v případě náhrady za naftu v zemědělství za období let 2000–2005. Z analýzy vyplývá, že hmotnostní produkce polutantů za období 2000–2005 by se snížila u CO o 4 %, u SO_2 o 28 %, u PM o 52 % a u VOC o 4 %, zatímco u CO_2 by se naopak zvýšila o 20 % a u NO_x o 32 %. Regresními rovnicemi je vyjádřen vývoj hmotnostní produkce jednotlivých polutantů z bionafty a z nafty v období 2000–2005. Z koeficientů spolehlivosti, které jsou konstantní, vyplývá, že vývoj hmotnosti polutantů z nafty kopíruje vývoj polutantů z bionafty. Význam dosažených výsledků spočívá v tom, že zpřesní celkovou bilanci emisí jednoho z tzv. ostatních mobilních zdrojů v ČR (mimo resort dopravy), a tím mimo jiné přispěje k upřesnění celkové hmotnosti produkce emisí v rámci REZZO 4 .

Klíčová slova: nafta motorová; bionafta; emisní faktor; normativní hmotnost nafty; velikost oseté plochy; limitovaná škodlivina; polutant; emise

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