Agricultural particulate matter emissions in the Czech Republic

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Abstract

Recent studies have demonstrated adverse effect of particulate matter on human health. Area of the Czech Republic, where is annual limit value of PM10 exceeded, permanently increases. In order to prepare effective measure of air quality improvement we have to compose complete emission inventory. One item, that in Czech emission inventories is missing, is emissions of agriculture activities. On preparation emission inventories are national emission factors preferred. In the Czech Republic no agriculture emissions were realized, therefore we will adapt USEPA method.
Basic operations on arable farming are:
- soil preparation
- harvesting
- transport
- unloading
- post harvest treatment

Emissions from transport, unloading and post harvest treatment are included in other source categories for that reason we will deal with soil preparation and harvesting. According to USEPA emission factors from this operations are depended on
- soil type respective its silt content
- weather conditions
- species of vegetal products
- method of soil preparation

All the above items will be incorporated into emission factors.

For emission estimation from animal farming it was taken into account species and age structure of animals in the Czech breeds and breeding technique.

Keywords: asrable farming, animal farming, PM emissions, agricultural operations

Introduction

Agriculture particles are emitted from both animal and plant production. Their composition is very various and depends on particle origin. Particles from plant production include soil minerals, organic material from plants, pollen and fungal spores. From animal production there are particles coming from feed, rest of skin and hairs and also dry manure (Atmospheric emissions of particulates from agriculture: a scoping study, 2000). Agricultural bioaerosols cause respiratory disease and some matter presented in this aerosol cause allergic reaction of skin, eye and nasal mucosa. Agricultural emissions come from housed livestock, arable farming, crop storage, energy used on farms and unpaved roads on farm. The emission from energy used and crop storage have been included in our inventory for that reason we try to estimate emission from housed livestock and arable farming in this paper. The emission estimation from housed livestock is based on methodology presented in AEI Guidebook (2006). Since the chapter on arable farming emissions is not available the emission estimation for this source category is based on USEPA methodology.

Arable farming

The current version of AP-42 (i.e., the 5th edition) does not address agricultural tilling even though a PM10 emission factor for fugitive dust generated by agricultural tilling was developed by Midwest Research Institute in 1983 and adopted by the USEPA in their 4th edition of AP-42. Thus, the methodology adopted by the California Air Resources Board (CARB) (Countess Environmental (2004) WRAP Fugitive Dust Handbook) is presented as the primary emissions estimation methodology in lieu of an official EPA methodology for this fugitive dust source category.

The way of tilling fields, the soil and climatic conditions in Mid-West is very different from conditions in the Czech Republic therefore it was necessary to adapt this emission model.

The USEPA (NATIONAL AIR POLLUTANT EMISSION TRENDS, 1900 – 1998, 2000) has published a general empirical formula for dust emissions due to land preparation, which can be used to estimate the amount of particulate matter (PM10, PM2.5) generated per acre-pass.

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$$E = k \times S^{0.6} \times a \times c \times p \quad (1)$$

where
S = % silt content of the soil defined as the mass fraction of particles smaller than 75 µm diameter found in soil to a depth of 10 cm (%)
a = field area
c = constant emission factor (c = 4.8 lbs/acre-pass)
p = number of tilling

The amount of emission depends on soil type only not on the type of working operation for this type of emission estimation. Modified model takes the type of working operation into account but there is no dependence on character of soil under the plough (cultivated land). For this reason the following relation for emission estimation is applied.

$$E = k \times S^{0.6} \times \sum a_j \times \left(\sum EF_i\right) \quad (2)$$

where
E = PM emissions
k = dimensionless particle size multiplier (EPA default is for PM10 = 0.21, PM2.5 = 0.042)
S = weighted mean % silt content of the soil in the Czech Rep.
a_j = areas under farm crops for each individual crops
$\sum EF_i$ = sum of emission factors for individual working operation using during the field works performed for the most frequently grown plants during the year

Nature conditions of Czech Republic

The Czech Republic is a landlocked country located in moderate geographical latitudes in the Northern Hemisphere. The climate of the Czech Republic can be labeled as moderate, of course with great local diversity seen throughout the year. The most important factor in the diversity of the Czech climate remains the varied topography, thanks to which the climate varies among individual regions of the country. These factors cause regional differences of air temperature, precipitation amount, winds and consequently the variability of soil moisture.

Soil types and methods of their agriculture cultivation

All above mentioned climatic factors influence the methods of agriculture soil cultivation. The way of soil preparation depends on the amount of precipitations in autumn. This is the time for sowing of winter wheat and rape. Generally speaking the dryer autumn the more procedures are needed for land preparation for sowing.

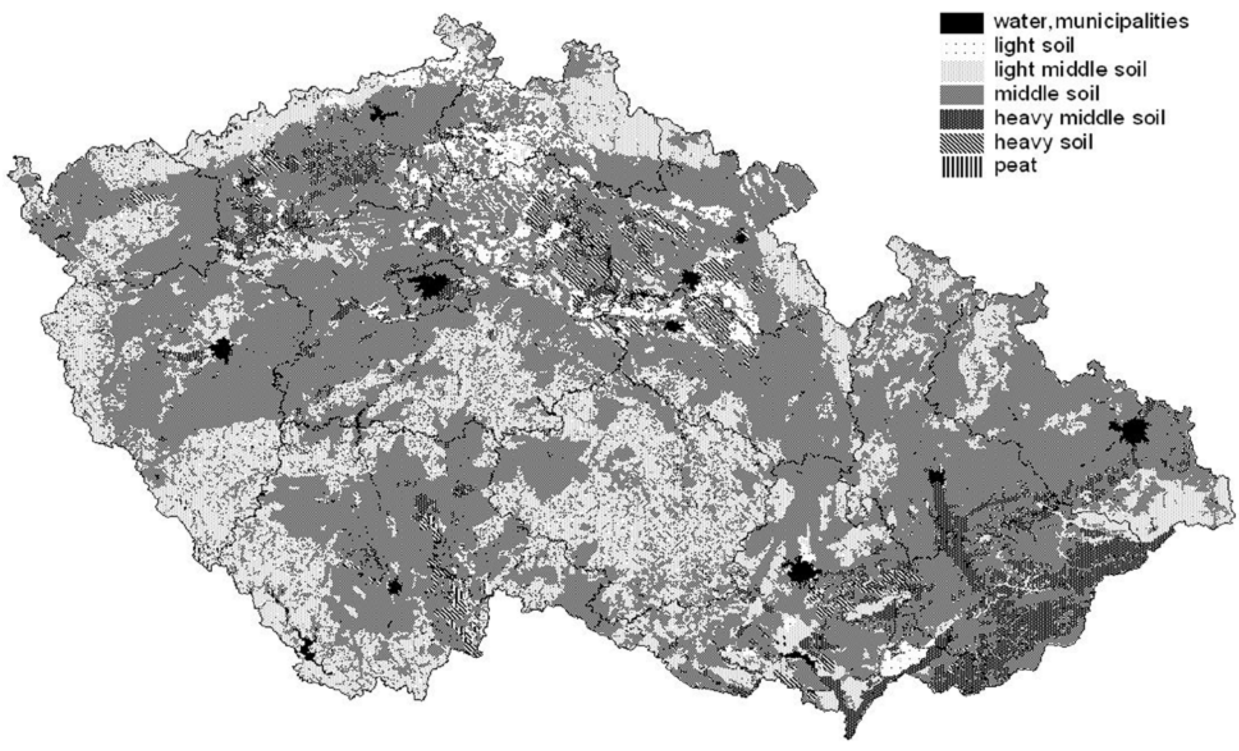

Figure 1:
Soil map of Czech Republic

Another factor that influences agriculture soil cultivation and PM emission during the field works is the soil type. The soil map of the Czech Republic is presented on figure 1.

According to the Czech classification (Petr J., et al. 1989), the major part of soils in the Czech Republic falls in category "middle". This category implies "loam" and "silt loam" categories according to triangle classification. The Czech soil classification and the triangle one are compared in table 1. The weighted mean of silt content amounts to 40 % in the Czech Republic.

Table 1:
Soil classification

Czech Soil Type	Soil Type texture triangle	Silt Content (%)
light	sand	12
light middle	loamy sand	12
	sandy loam	33
middle	silt loam	52
	loam	40
heavy middle	clay loam	29
heavy	clay	29

On the base of data from the Statistical yearbook (2006) there were selected crops whose areas under crops cover about 80 % of arable soil in the Czech Republic. For these corps there were specified the typical operations of land preparation. These operations were chosen from Czech publications (Petr J. et al. 1989, Autorský kolektiv 1998, Pulkrábek J. 2003) and consulted with farmers (see table 2 and table 3). Emission factors were selected from the work (Bogman P. et al. (2007). Emission factors published in this study stem from measurements which were provided for the soil type with the silt content amounting to 40 %.

This value corresponds to the weighted mean content of silt in soils in Czech Republic. The equation (2) transforms into

$$E = k \times \sum a_j \times \left(\sum EF_i\right) \qquad 3$$

because formula $\sum EF_i$ includes of soil texture influence.

A soil preparation for seeding is divided into operations for spring and winter crops. The first ones always emit less dust particles then autumnal operations, because the soil is mostly moist by spring when they are performed. This was also the reason why the emission factor for floating has been decreased for spring compared to the autumn season. Furthermore, it should be mentioned that demands for working operations for particular crop may differ even within one farm and depend on factual soil conditions. Emissions for the Czech Republic were calculated according to formula 2, where we take B = 1 for S = 40 % as a typical value in the Czech Republic.

Table 2:
Agriculture operations for winter cereals and winter rape

Winter crops			
Wet autumn		Dry autumn	
Operation	TSP emissions (kg/ha)	Operation	TSP emissions (kg/ha)
root cutting	1.26	root cutting	1.26
discing, tilling, chiseling	4.5	discing, tilling, chiseling	4.5
fertilizing	0.6	fertilizing	0.6
floating	4.5	2x floating	9
seeding	4.5	seeding	4.5
spraying	0.6	spraying	0.6
harvesting	5.5	harvesting	5.5

Table 3:
Agriculture operations for spring cereals, corn and sugar beet

Spring crops	
Operation	TSP emissions (kg/ha)
root cutting	1.26
ploughing	4.5
fertilizing	0.6
floating + seeding	2.5
spraying	0.6
harvesting[1]	5.5
for corn and sugar beet cultivation	3

[1]without sugar beet

Results of arable farming emissions assessment for the Czech Republic

Results of assessment of emissions from arable farming in the Czech Republic are summarized in table 4 and compared with those estimated according to RAINS methodology (http://www.iiasa.ac.at/web-apps/apd/RainsWeb/RainsServlet1). The RAINS estimates show significantly lower values. The reason for this fact is a need for application of more operations, because only about one half of Czech farms are equipped with advanced technologies enabling matching of several working operations. Zero-tillage approaches are not appropriate for all regions of Czech Republic, especially for spring crops. These technologies are applied in limited extent because their application for heavy-textured soils is too energy-consuming.

Table 4:

Czech emission from arable farming, 2005

	Unit	Emissions	Emissions according to IIASA
TSP		55535	4990
PM10	Mg/year	11662	274
PM2.5		2332	0

The emissions from arable farming are not insignificant and furthermore they are concentrated on several months in year. Monthly variability in agricultural operations is showed in table 5.

Table 5:

Monthly variabilities in agricultural operations

Crop	Jan		Feb		Mar		April		May		Juny		July		Aug		Sept		Oct		Nov		Dec	
winter wheat														■	■	■	■	■	■	■	■			
spring wheat					■	■									■	■	■	■	■	■	■			
winter barley													■	■	■	■	■	■	■	■	■			
spring barley						■	■								■	■	■	■	■	■	■			
Triticale															■	■	■	■	■	■	■			
Oats						■	■										■	■	■	■	■			
Rye																	■	■	■	■	■			
Rape													■	■	■	■	■	■	■	■	■			
Grain maize						■	■										■	■	■	■	■			
Industrial sugar.beet						■	■													■	■			
Green and silage maize						■	■										■	■	■	■	■			
Other annual fodder crops						■	■										■	■	■	■	■			
Lucerne						■	■										■	■	■	■	■			
Red clover						■	■										■	■	■	■	■			
Other perennial fodder crops						■	■										■	■	■	■	■			

Table 6:

Emission from animal breading, 2005

		Ratio	EF PM10 kg/animal	EF PM2,5 kg/animal	Number 1000 head	PM10 Mg	PM2,5 Mg
Dairy cattle	Tied or litter	0.90	0.36	0.23	564.00	183	117
	Cubicles (slurry)	0.10	0.70	0.45	564.00	39	25
Beef cattle	Solid	0.90	0.24	0.16	598.00	129	86
	Slurry	0.10	0.32	0.21	598.00	19	13
Calves	Solid	0.90	0.16	0.10	212.00	31	19
	Slurry	0.10	0.15	0.10	212.00	3	2
Sows	Solid	0.00	0.58	0.09	229.00	0	0
	Slurry	1.00	0.45	0.07	229.00	103	17
Weaners	Solid	0.00	na	na	975.00	0	
	Slurry	1.00	0.18	0.03	975.00	176	28
Fattening pigs	Solid	0.00	0.50	0.08	1630.00	0	0
	Slurry	1.00	0.42	0.07	1630.00	685	112
Horses	Solid	1.00	0.18	0.12	23.00	4	3
Laying hens	Cages	0.95	0.02	0.00	6316.00	102	13
	Perchery	0.05	0.08	0.02	6316.00	27	5
Broilers	Solid	1.00	0.05	0.01	19420.00	1010	132
Total emissions (Mg/year)						2511	572

Animal farming

Unlike arable farming, the procedure of emisions assessment from animal breeding is described in the Guidebook. Resulting emissions correspond to RAINS emissions estimates.

For emission estimation from animal farming, species composition and age structure of animals in the Czech breeds and breeding techniques were taken into account.

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