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Analysis of samples occasioned during the period of the erosive dangerous winds

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Abstract

Wind erosion is a natural phenomenon. The wind is acting on the soil surface with its mechanical force. It also erodes the soil and releases soil particles that are set in motion. The wind transmits the soil particles to a different distance, where are stored when there is a reduction in wind speed. The work deals with the comparison of the samples, which were collected by device for catching soil particles ("general deflameter") with active trap soil particles and time recording ("deflameter") at the time of occurrence of erosion dangerous winds. Deflameter with active trap soil particles and time recording allows monitoring of the qualitative and quantitative properties including time recording of macroscopic and microscopic soil particles, carried by the wind. Measurements were carried out at three locations in the South Moravian Region on the soil surface without vegetation.

Key words: deflameter, wind erosion, wind speed

Introduction

Wind erosion is one of the many causes of serious threats to production and non-production functions of agricultural soils. The erosion deprives the soil of the most fertile part, reduces the amount of nutrients and humus, damaging crops and impedes movement of machinery for land and causing losses of seeds and seedlings. It is reported that wind erosion in Moravia is already currently threatened 45% of agricultural land (JANEČEK, 2007). Wind transports soil particles that may also contribute to air pollution as part of the airborne dust and thus negatively affects the health of the population.

Climate change scenarios and the climate models predict a significant increase in climate aridity of the Czech Republic by the year 2100. It is likely that the South Moravia Region will be increasingly endangered by the drought. (KALVOVÁ et al., 2002). Reduction of soil moisture will have an adverse impact on soil and will result in wind erosion (MATEJKA et al. 2004, ROŽNOVSKÝ a KOHUT 2004). These changes could have a significant impact on increasing the vulnerability of the soil to wind erosion (DUFKOVÁ a TOMAN, 2004).

Two basic factors affect the emergence of wind erosion. The first factor is the weather, especially wind speed, its duration and frequency of occurrence. Sometimes only a low wind speed can cause the movement of soil particles. The second important factor is the soil moisture. Wind erosion can be observed especially in drier and warmer climate areas with light soils. The most likely period of threat of wind erosion is in spring (March to May) and autumn (September to November). In this time the high wind speed occurs and the soil is not covered by vegetation.

Literature indicates only the approximate value of the size of soil particles, which are subject to erosion (particles in the range of 0.05 to 0.5 mm, larger and heavier particles 0.5 to 2 mm). The critical wind speed, at which the wind erosion occurs, ranges from 8.0 $m.s^{-1}$ to 22.0 $m.s^{-1}$ according to the soil type (CHEPIL, 1958).

Materials and methods

Potential threat of soil to wind erosion can be based on analysis of pedologic and climatic data (light soil in arid areas). This determination is not complicated. On the other hand monitoring of actual wind erosion is rather challenging. In addition to a detailed analysis of the wind field, the current amount of suspended soil particles must be recorded and evaluated. Due to the lack of simple and effective device for field research for current threat of soil to wind erosion a direct measurement of wind erosion was carried out only sporadically. It is possible to detect the relative amount of eroded particles with various constructions of passive device for catching soil particles (passive deflameter), but not the date of occurrence of erosion episodes. In 2012 the patent of "deflameter with active trap soil particles and time recording" was inscribed. The owners of a utility model are Czech Hydrometeorological Institute, Prague – Komořany and Research Institute of Soil and Water Conservation, Prague. Originators are Ing. Hana Středová, Ph.D. and Ing. Jana Podhrázská, Ph.D. and Ing Tomáš, Středa, Ph.D. It combines also a measurement of wind speed. Deflameter with active trap soil particles and time recording allows monitoring of the qualitative and quantitative properties including time recording of macroscopic and microscopic soil particles, carried by the wind. This deflametr was developed to determine the relative amounts of soil particle and composition of soil particles eroded by wind and to determine the actual soil erosion.

The available data on current wind conditions and current weather conditions (especially in period without vegetation cover) were continuously monitored and evaluated. The field measurements held depending on the weather.

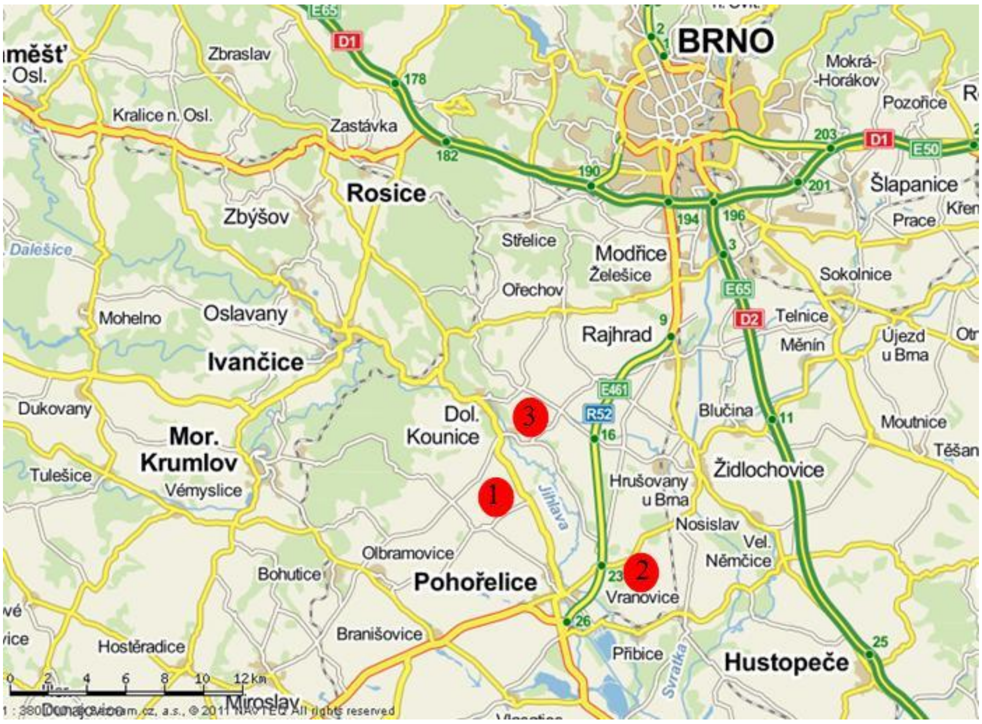

Fig. 1 Map of the field research, three locations, source: http://mapy.cz/, adjusted by the author

Based on the analysis of the state of soil the vulnerable erosion locations were identified. The South Moravian Region was area of interest in terms of good accessibility and greater flexibility for the research team. Fig. 1 shows the location of the three sites. The soil sampling for subsequent laboratory analysis (determination of grain size) was performed from monitored areas.

The field research at the first location (Fig. 1, number 1) was held on 24. 5. 2012. The type of soil is sandy-loam. Another location is shown in Fig. 1 (number 2) and field measurement was there on 15. 3. 2014. Soil is also sandy-loam. Last measurement was carried out on 19. 4. 2014 (Fig. 1, number 3) and the soil is loamy.

Simultaneous measurements of wind speed and soil particles (trapped by deflameter) allowed comparison of spectrum of these particles with a specific value of the wind speed. Wind speed was measured by an anemometer as a part of deflametric measurement (25 cm above the surface). Subsequently the laboratory analysis of deflametric records was determined. The method of digital image analysis using a microscope OLYMPUS CX 41 and QuickPHOTO Micro Software 2.3 with the function of measuring the size of objects was used. In combination with meteorological measurements of wind speed (anemometer registering wind speed in one-second frequency) it was possible to specify the conditions at the time of the episode.

Results

If we compare the histograms of the maximum wind speed (recorded by an anemometer, Fig. 2, 3 and 4), we find that in every episode of erosion the most frequent wind speed varies. The most recorded wind speed was between 8.00–9.00 $m.s^{-1}$ on 24. 5. 2012, episode 15. 3. 2014 the wind speed was between 11.00 and 12.00 $m.s^{-1}$ and 19. 4. 2014 it was between 9.00 and 10.00 $m.s^{-1}$. The highest maximum wind speed was recorded on 15. 3. 2014; 13.69 $m.s^{-1}$ (Tab. 1), which can be also seen in the box plot (Fig. 5).

Fig. 6 shows a histogram of the particle size observed by deflameter on 24. 5. 2012. Average particle size was 47 μm. The largest measured particles analyzed in this period corresponded to 559 μm. The number of measured particles was 17 959.

Tab. 1 Statistic of the maximum wind speeds

MAX wind speed	Average	Median	Maximum	Standard deviation
24.5.2012	8,68	8,60	12,02	1,39
15.3.2014	10,53	10,87	13,69	1,91
19.4.2014	9,48	9,34	10,64	0,78

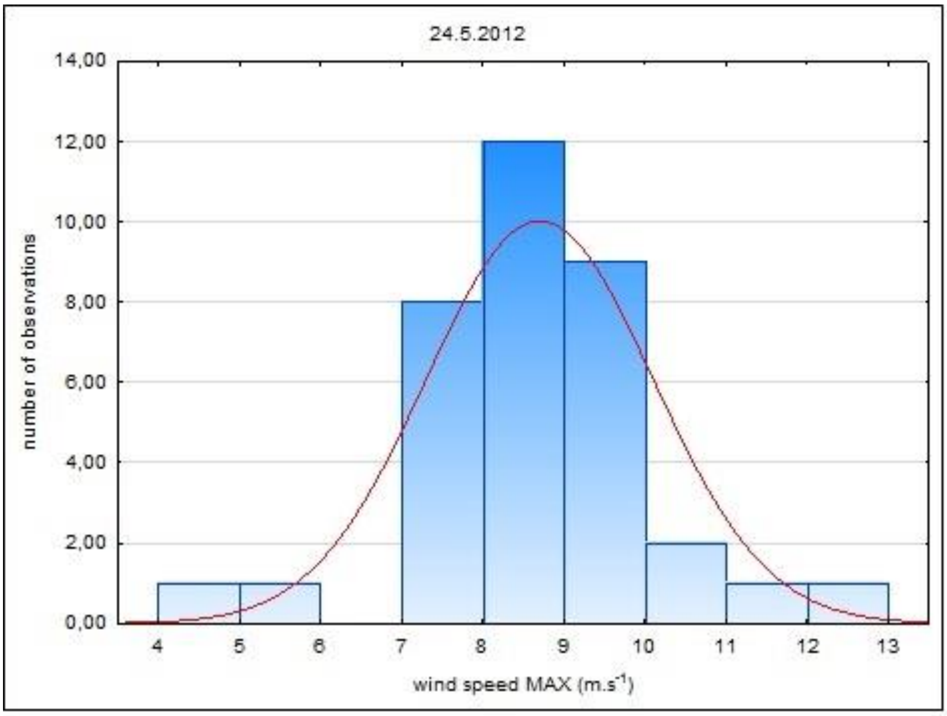

Fig. 2 Histogram maximum wind speed, 24.5.2012

Another histogram particle size (15. 3. 2014, Fig. 7) shows an average particle size of 33 μm. The largest measured particles analyzed in this period corresponded to only 287 μm. The total measured amount of particles using the software was 6 555. This episode was poorer in the number and size of particles, but the wind speed was measured as the highest.

The last histogram particle size (19. 4. 2014, Fig. 8) can be enumerating the smallest average particle size of 32 μm. The largest measured particles analyzed in this period corresponded to 377 μm. It was measured the largest total quantity of particles of all measurements (29 635).

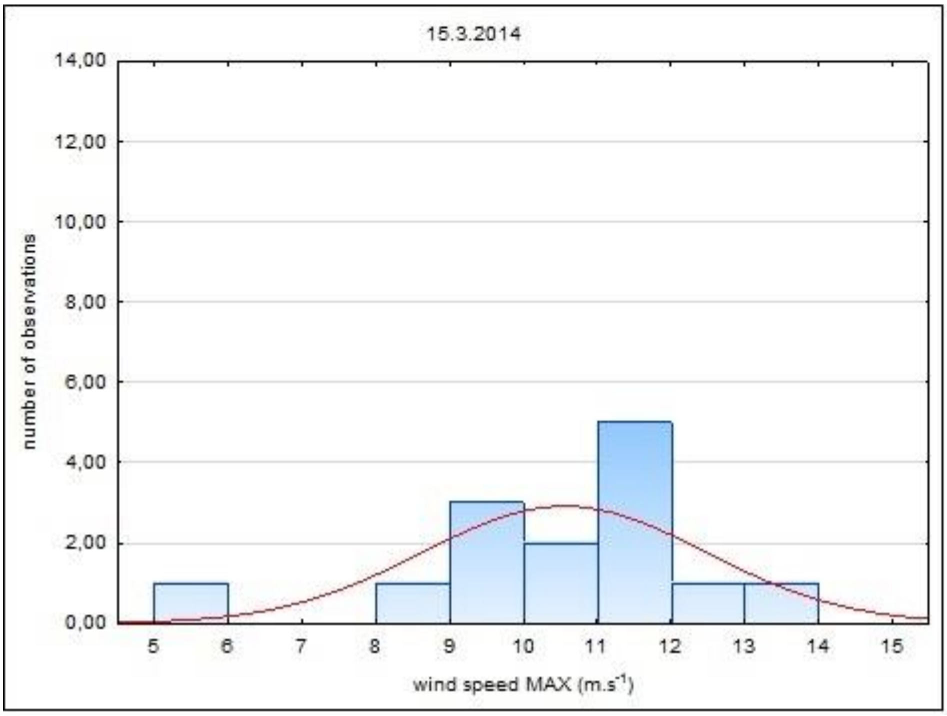

Fig. 3 Histogram maximum wind speed, 15.3.2014

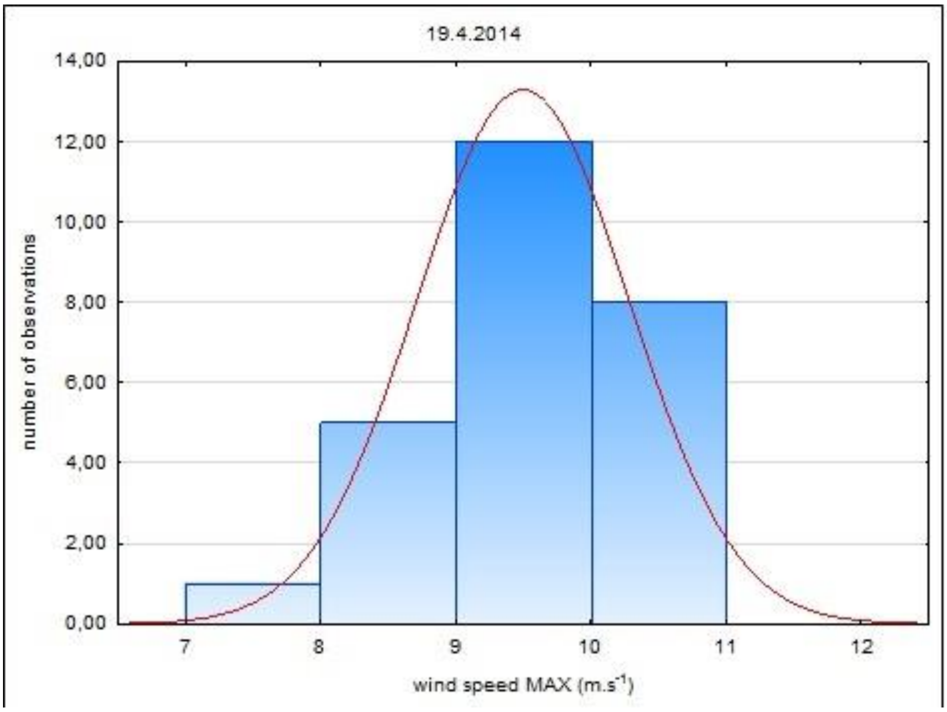

Fig. 4 Histogram maximum wind speed, 19.4.2014

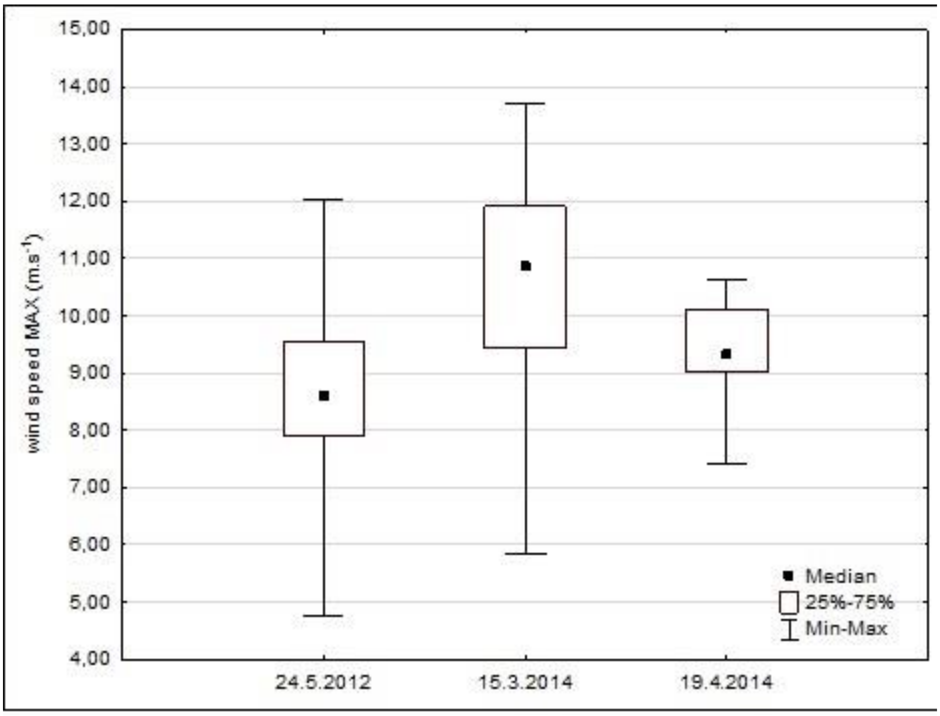

Fig. 5 Graph of maximum wind speed measured in three locations, 24.5.2012, 15.3.2014, 19.4.2014

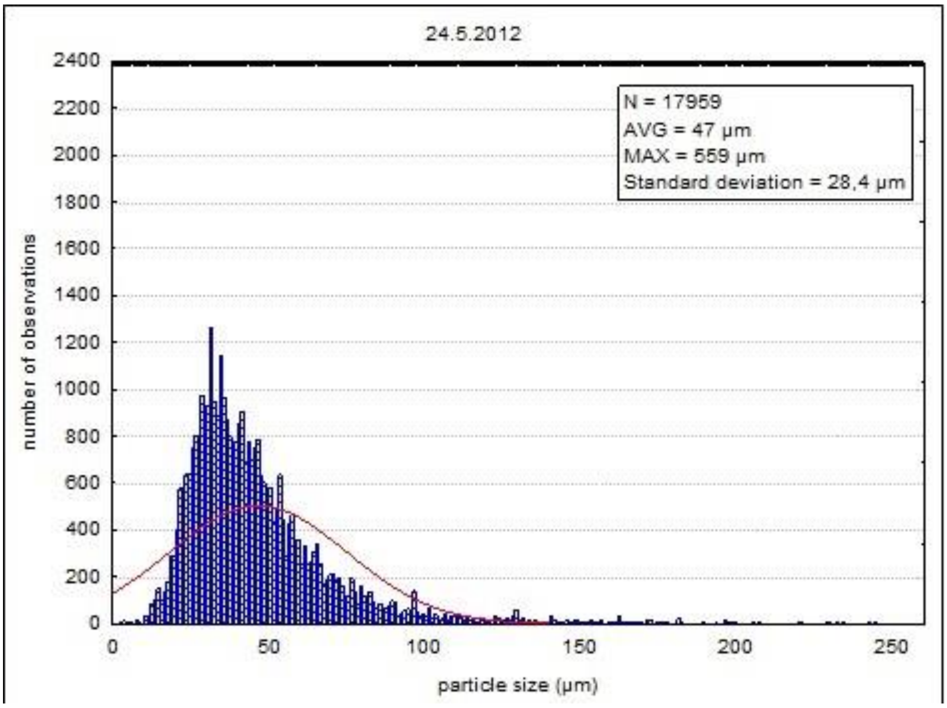

Fig. 6 Histogram particle size, 24.5.2012

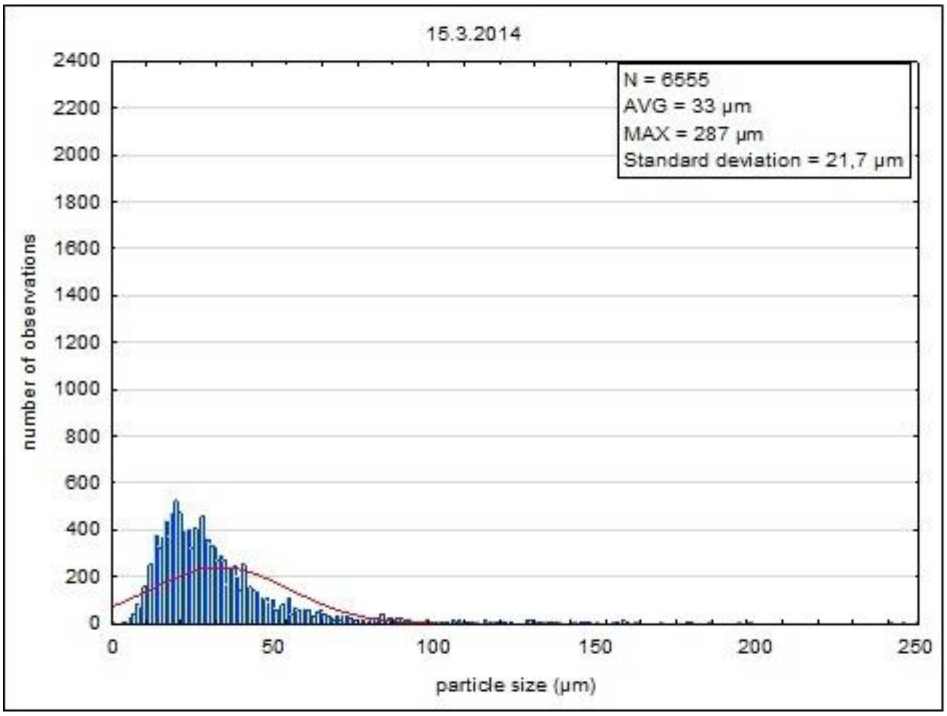

Fig. 7 Histogram particle size, 15.3.2014

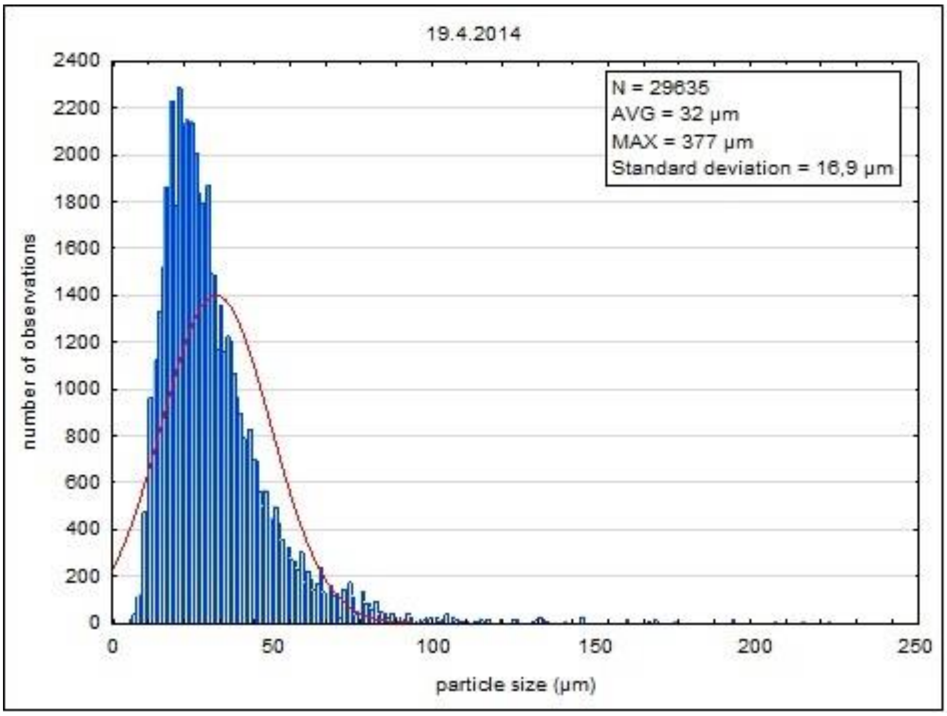

Fig. 8 Histogram particle size, 19.4.2014

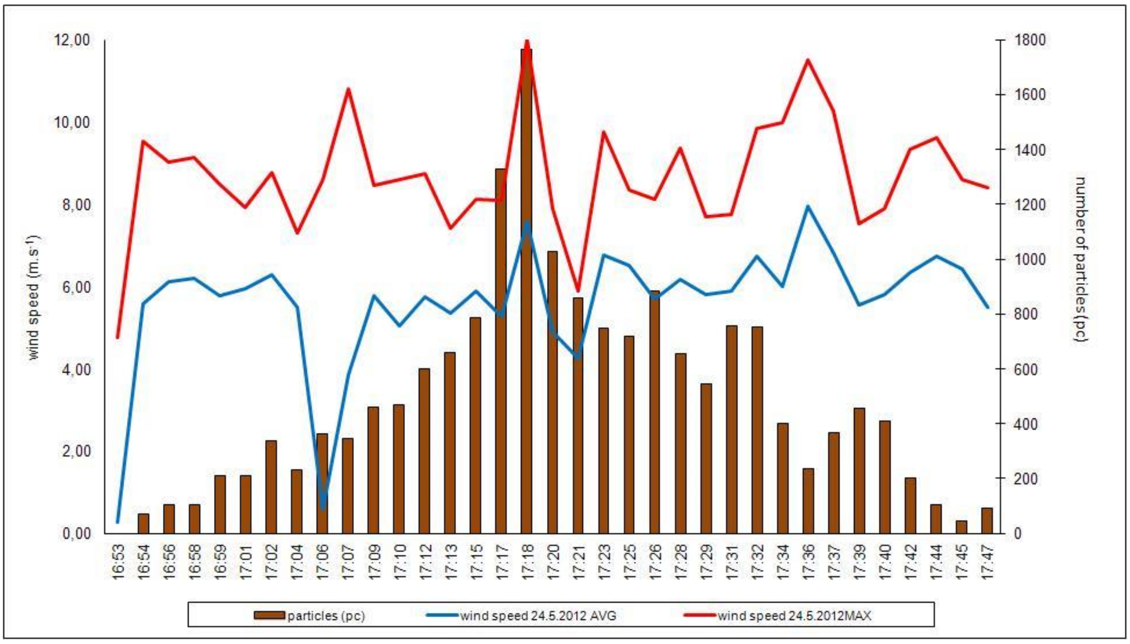

Fig. 9 Graph of the wind speed and distribution of the number of particles in time, 24.5.2012

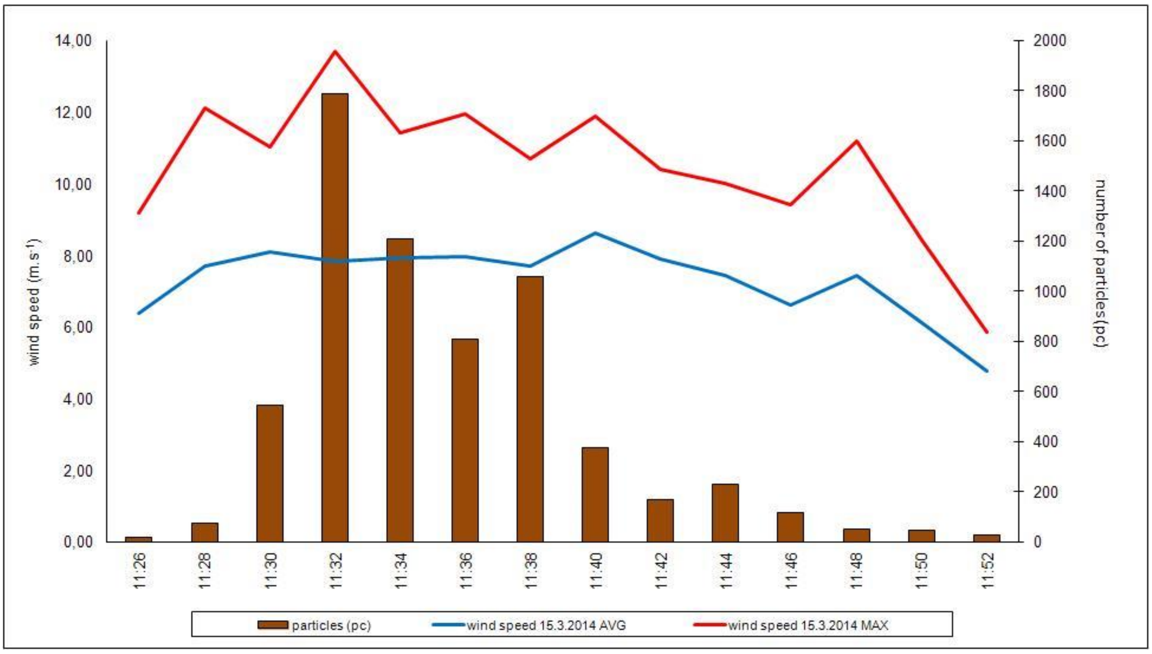

Fig. 10 Graph of the wind speed and distribution of the number of particles in time, 15.3.2014

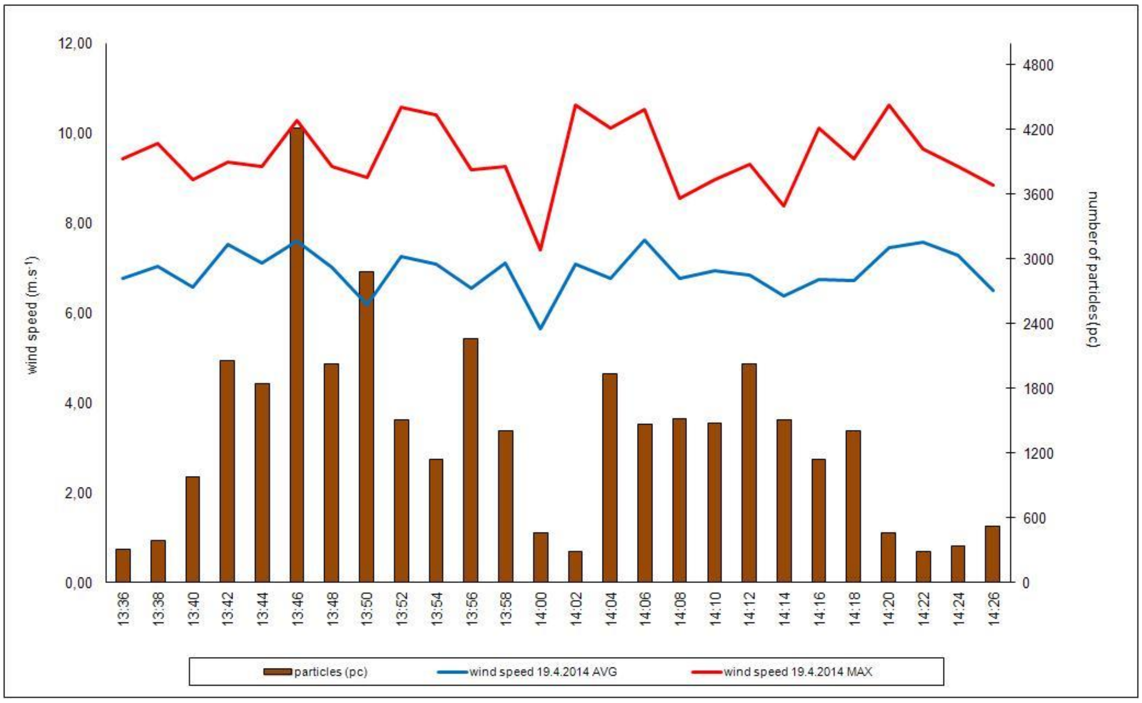

Fig. 11 Graph of the wind speed and distribution of the number of particles in time, 19.4.2014

The graphs in Fig. 9, 10 and 11 show the behavior of individual episodes of erosion (max and average wind speed), accompanied by the distribution of the number of particles in time as they were recorded by deflameter. It is evident that there is not always the number of particles coincided with the course of the wind speed. On the other hand, in each measurement there is at least one section in which it is. In the episode of 24. 5. 2012 it is in the time 17:18, when the largest number of particles (1754) and considerable wind speed (12.02 $m.s^{-1}$) was registered. In this case, it was the highest maximum winds speed of the entire measurement. The same case was during the episode of 15. 3. 2014, when deflameter recorded 1787 particles at 11:32. Thus, the largest number of particles correlates with the highest maximum wind speed that was recorded (13.69 $m.s^{-1}$). The episode dated 19. 4. 2014 does not support this trend. The highest maximum wind speed was measured twice (14:02 and 14:20), but the highest amount of the particles (4 212) were recorded by deflameter at 13:46 with a maximum wind speed of 10.29 $m.s^{-1}$. On the other hand, it must be said that there is a noticeable decrease in wind speed. At 14:00 the lowest maximal wind speed was observed (7.40 $m.s^{-1}$) and also a low number of measured particles (successively 464 and 288), which was subsequently increased depending on increasing of the wind speed. The example of dust particles from this episode is shown in Fig. 12.

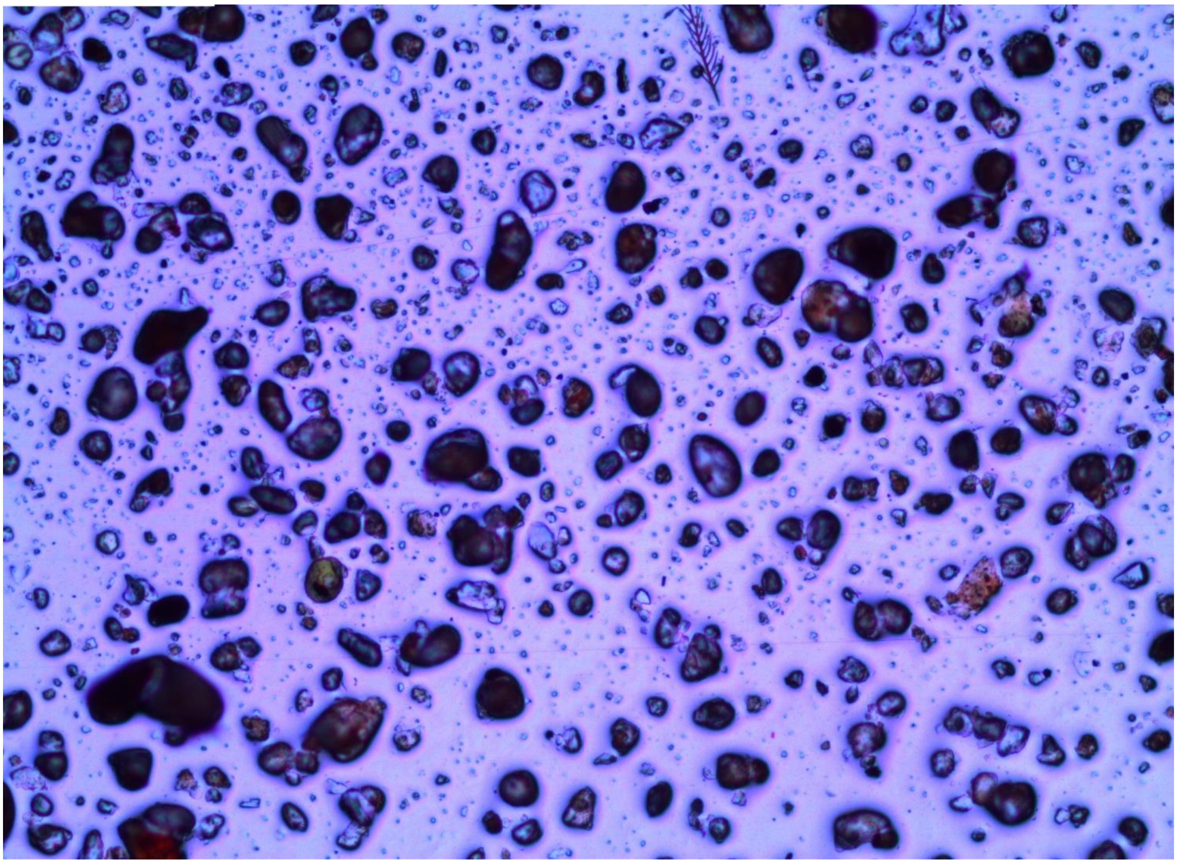

Fig. 12 Example of the dust particles, 19.4.2014

Conclusion

The aim of this work was the analysis of deflametric records occasioned during the period of the erosive dangerous winds evaluated in areas of the South Moravian Region, in days 24. 5. 2012, 15. 3. 2014 and 19. 4. 2014. So it was the period without vegetation on the soil surface. The deflametric samples were acquired through field research and were evaluated in a laboratory by a microscope. Thanks to this, the relative amount and grain size of dust particles eroded and drifted by the wind were determined. Also the exact time of particle transport was identified

The largest wind gusts were identified. They reached 12.02 $m.s^{-1}$ (24. 5. 2012), 13.69 $m.s^{-1}$ (15. 3. 2014), 10.64 $m.s^{-1}$ (19. 4. 2014). High wind speeds were accompanied by obvious signs of soil particles drift.

The largest measured size of transported particle analyzed under these erosion conditions correspond to 559 μm (sandy-loam soil on 24. 5. 2012), 287 μm (sandy-loam soil, 15. 3. 2014) and 377 μm (loamy soil, 19. 4. 2014). The largest total amount of dust particles measured by the software was 29 635 (19. 4. 2014).

The result of this work will be a risk assessment methodology of wind erosion, which will be used to evaluate the degree of threats to soil. Outputs at least partially confirmed how much the wind erosion contributes to air pollution caused by suspended particles.

Since it was confirmed that a high wind speed under suitable conditions (surface without vegetation, the absence of obstacles, drought) has the ability to abduct soil particles sizes of 50 μm or more, but also particles of much smaller dimensions. Simply said, the wind transports soil particles that may contribute to air pollution as part of the airborne dust and thus negatively affects the health of the population. It is planned a continuation in field measurements and further analysis of soil particles.

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Summary

Problémem současné zemědělské krajiny je tzv. nadměrná (zrychlená) eroze zemědělské půdy, kdy dochází k odnosu povrchových vrstev půdy rychlostí vyšší než rychlost přirozené tvorby půdy z půdotvorného substrátu. Větrná eroze je jedna z mnoha příčin vážného ohrožení produkční i mimoprodukční funkce zemědělských půd. Transportované částice, které jsou větrem unášeny, a na ně vázané látky způsobují především poškozování klíčících rostlin, znečišťování ovzduší a škody navátím ornice. Na vznik větrné eroze mají vliv dva základní faktory. Prvním je faktor meteorologický, především rychlost větru, doba jeho trvání a četnost výskytu. K pohybu půdních částic stačí někdy i malé rychlosti větru. Druhým důležitým faktorem je struktura a vlhkost půdy. Větrnou erozi můžeme zaznamenat především v sušších a teplejších klimatických oblastech s lehkými půdami. Jaro (březen až květen) a podzim (září až listopad) jsou období s nejvýznamnějším ohrožením půdy větrnou erozí. Vyskytují se

totiž rychlosti větru, které jsou erozně nebezpečné, a půda je bez vegetačního krytu.

Práce si kladla za cíl analyzovat deflametrické záznamy, které byly pořízeny díky polním měřením v období výskytu erozně nebezpečných rychlostí větru v Jihomoravském kraji ve dnech 24. 5. 2012, 15. 3. 2014 a 19. 4. 2014. Tedy době, kdy půda není kryta vegetací. Následně byly deflametrické záznamy vyhodnoceny v laboratoři pomocí mikroskopu. Tím bylo stanoveno relativní množství a zrnitostní složení prachových částic erodovaných a unášených větrem a byl také určen přesný termín transportu částic.

Byly zjištěny nejvyšší nárazy větru, které dosahovaly 12,02 $m.s^{-1}$ (dne 24. 5. 2012), 13,69 $m.s^{-1}$ (dne 15. 3. 2014), 10,64 $m.s^{-1}$(dne 19. 4. 2014). Vysoké rychlosti větru byly provázeny zřejmými projevy vznosu půdních částic. Největší naměřené částice analyzované v těchto erozních epizodách dosahovaly rozměru 559 µm (písčito-hlinitá půda, dne 24. 5. 2012), 287 µm (písčito-hlinitá půda, 15. 3. 2014) a 377 µm (hlinitá půda, dne 19. 4. 2014). Největší celkové množství prachových částic naměřených pomocí software bylo 29 635 (dne 19. 4. 2014).

Výsledkem práce je především metodika hodnocení rizika větrné eroze, která poslouží k vyhodnocení míry ohrožení půdy. A to z pohledu současného stavu i při možných vývojích klimatu. Výstupy alespoň částečně potvrdily, jakou měrou se větrná eroze podílí na znečištění ovzduší suspendovanými částicemi. Jelikož bylo potvrzeno, že vysoká rychlost větru má za vhodných podmínek (povrch bez zapojené vegetace, nepřítomnost překážek, bezesrážkové období apod.) schopnost unášet půdní částice o velikostech 50 µm a více, avšak i částice mnohem menších rozměrů. Do budoucna je plánované pokračovaní v měření v terénu a další analyzování půdních částic zachycených deflametrem. Důležité bude sledovat předpověď povětrnostních podmínek, které budou z hlediska nebezpečí větrné eroze nejvhodnější.

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