The influence of meteorological conditions on PM_{10} concentrations in Suceava City (North - Eastern Romania)

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ABSTRACT: Air quality evaluation is important for assessing the nature, concentration thresholds and environmental impacts of atmospheric pollution. Airborne pollutants are related to weather elements which affect their transport and diffusion patterns. Particulate matter concentrations (PM) often exceed the threshold values at which human health is severely affected, especially in urban areas. This paper presents the first assessment of PM_{10} concentrations in the urban environment of North-Eastern Romania, at mid elevations, in relation to particular meteorological conditions. We hereby determine the influence of temperature, rainfall, humidity, atmospheric pressure and wind direction and speed on the concentrations of PM_{10} in the urban area of Suceava City, during the recent period (2008-2010). The results of our study have shown that the PM_{10} concentrations were highest in the cold season, during cloudy days and in cases of temperature inversions. We also found that for our study area the overall PM_{10} concentrations appear influenced to a great extent by wind at both maximum and average speed, and by precipitation. Our results were similar to other findings in the urban areas of South-Western Germany, South-Eastern Spanish Mediterranean Basin and Turkey.

KEY WORDS: PM_{10}, meteorological parameters, air pollution, Suceava City, PCA

1. Introduction

Air quality evaluation is important for assessing the nature, concentration thresholds and environmental impacts of atmospheric pollution. Particulate matter (PM) represents a common air pollutant which has become a major concern for public health in recent years (WHO, 2003, 2013). Particulate matter is the general term used for a mixture of particles (solid and/or liquid) suspended in air, collectively known as aerosols, with a wide range in size and chemical composition. PM_{10} refers to the particles with a diameter ranging between 10 and 2.5 micrometers and represents the 'coarse particle' fraction in addition to the finest $PM_{2.5}$ (EEA, 2013). Annual average concentration of PM_{10} should not exceed 40µg/m^3, while the daily upper threshold value of 50µg/m^3 should not be recorded longer than a 35-days timeframe (OJ, 2008). PM_{10} has different sources that can be natural, such as wind entrainment of particles from the top soil or anthropogenic (traffic, energetic sectors, municipal dumps, building sites, landfills etc.). Particulate matter has a complex chemical composition that undergoes continuous change, depending on emission sources and atmospheric and weather conditions. Meteorological parameters such as wind speed, solar radiation, rainfall, temperature inversions, etc. affect PM chemical formation, diffusion and dispersion processes. Numerous studies were conducted that capture the influence of various meteorological conditions on PM_{10} concentrations across different European regions, and especially in urban areas (e.g. Houthuijs et al., 2001; Chaloulakou et al., 2003; Rost et al., 2009; Galindo et al., 2011; Unal et al., 2011; Bielawska et al., 2014 etc.).

However, for Romania, such studies are scarce and restricted to particular regions and elevations (e.g.Houthujis et al., 2001; Makra et al., 2013 etc.). For instance, Houthujis et al., (2001) found a clear seasonal variation of PM_{10} concentration in a range of important Eastern European cities, among, which four located in Romania. Makra et al., (2013) modelled the PM_{10} trajectories across the Bucharest metropolitan area as a function of selected meteorological parameters. The influence of wind direction on PM_{10} concentration at low elevations was highlighted in Botosani City, where the particulate matter frequently exceeded the maximum admitted values because of the winds that were dissipating the particles in the central areas of the city (Vieru et al. 2012). The influence of nebulosity on the air pollution in the Slatina City area was investigated by Constantin et al. (2014) who found that clouds with a great vertical development formed over the urban area provide the best conditions for dispersion of pollutants. Nevertheless, the majority of studies on PM_{10} are focused on the identification of sources and concentration thresholds, mainly in the Bucharest urban and industrial areas (e.g. Proorocu et al., 2014; Iorga et al., 2015 etc.). To date no studies assess the relation between other meteorological parameters and PM_{10} concentrations and dispersion patterns in the north-eastern part of the country, despite the fact that reports show frequent exceedances of maximum thresholds for urban areas located at mid elevations ((Environmental Protection Agency of Suceava City - APM SV), 2009; 2010).

The main objective of this study was to determine the influence of selected meteorological parameters, i.e. temperature, rainfall, humidity, atmospheric pressure, wind direction and speed, on the concentrations of PM_{10} in the Suceava City area (~300 m a.s.l.), North-Eastern Romania, during the recent period 2008 - 2010.

We specifically aim to:

- ❑ assess the PM_{10} data recorded by local monitoring stations between 2008 and 2010, according to the EU PM_{10} standards.
- ❑ investigate the relationship between PM_{10} on the one hand, and temperature, rainfall, humidity, atmospheric pressure, wind direction and speed, nebulosity, sunshine duration on the other hand.

2. Study area

Suceava is an average-sized-city located in the North-Eastern Romania (47°39′ N, 26°15′E), (Fig.1). It extends between the relatively smooth surface of Suceava Plateau, flanked in south-east by the presence of patches of meadow terrace, and middle course of the Suceava River. The absolute altitude varies between 320 and 345 m. The city develops mostly on the right bank of Suceava River, on a relief with slightly sloping hills between the Scheia and Cetatii streams. The general orientation of the interfluves is NW-SE (Cocerhan, 2012).

The local climate is moderate temperate continental, typical for hilly areas, with average temperatures of -2.8°C in winter and 18°C in summer. The annual mean rainfall is 620 mm. Most of the rainfall occurs in the warm season, with an average of 455 mm. The general dominant wind directions are NW (27.1%) and SE (10.3%), with an average speed of 2-3 m/s (Tanase, 2011).

3. Methods

3.1. Data collection

The PM_{10} concentrations data analyzed in the present study resulted from measurements performed by the Environmental Protection Agency of Suceava (APM SV) in the time interval 2008-2010. The APM SV monitors the air quality in Suceava City at two stations: SV1 and SV2. SV1 air quality monitoring station is located in the relatively central part of Suceava City, in a commercial - residential area and measures background levels of air pollutants. SV2 station is located in the Burdujeni area, at a lower elevation, and measures the impact of industrial activities on air quality in Suceava Valley (Tab. 1).

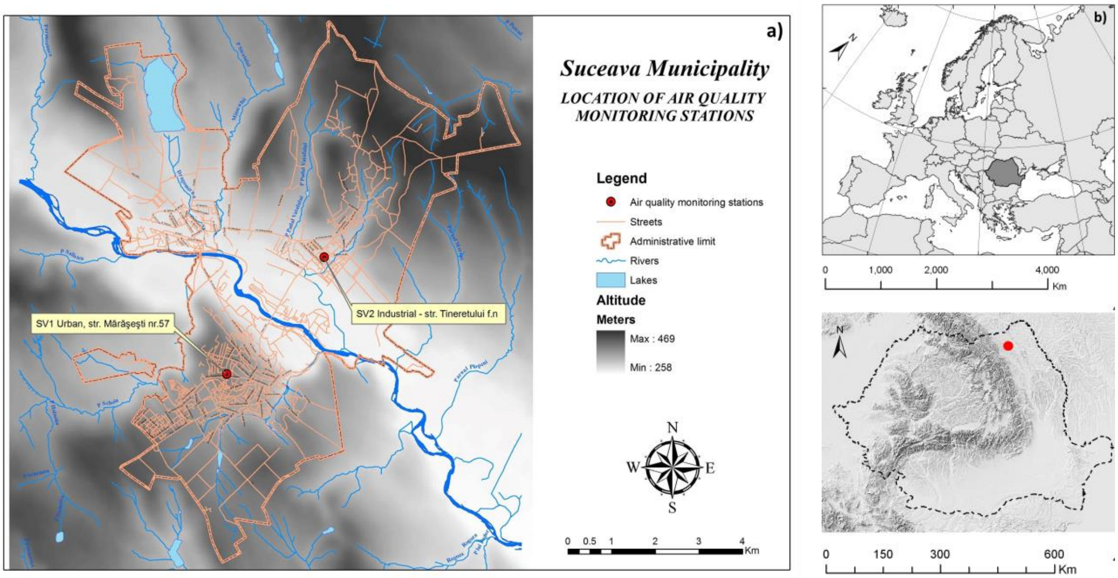

Figure 1 a) Location of air quality monitoring stations in Suceava City; b) location of Suceava City in Romania (red dot) and of Romania in Europe.

Table 1 The geographical coordinates, type and elevation of air quality monitoring stations in Suceava City

Air quality station	Latitude N	Longitude E	Altitude (m)
SV1 - Urban	47^{0}38’57,00’’	26^{0}14’57,12’’	376
SV2 - Industrial	47^{0}40’08,28’’	26^{0}16’52,80’’	289

PM_{10} concentrations were measured at SV1 only in 2008 and at SV2 since 2008. Because at SV2 station the PM_{10} concentrations often exceeded the maximum threshold value our study is based on data from this station. In total, 693 daily measurements of PM_{10} concentrations are available. Daily mean concentrations of PM_{10} were measured by determining the filter particulate mass gravimetrically, using a Sentinel TCR Tecora + sequential sampler and a control unit UNITEC FOX according to SR EN 12341/2002.

Ground-based meteorological data (e.g. air temperature, humidity, precipitation, wind speed and direction) necessary to investigate meteorological influences on PM_{10} concentrations were available from SV2 station but also from the Suceava weather station.

3.2. Data analysis

For deriving main relations between PM10 concentrations and selected meteorological parameters, a principal component analysis (PCA) was employed (Fig.16). Before applying the principal component analysis, the data were normalized using a Z-Score transformation. The PCA was computed using the PAST software (Hammer et al., 2001). The first two principal components (PC1 and PC2) explain over 60% of the total variance (38 and 24% respectively), whereas PC3 explains 18%. Hence, only the first two components were further discussed in our study. Regression analysis was used to clearly show the correlation between PM_{10} concentrations and each of the meteorological parameters discussed.

4. Results and discussion

4.1. Variation of PM_{10} concentrations in the Suceava City area during the 2008-2010 timeframe

In 2008-2010 the recorded PM_{10} concentrations in Suceava City were high. Of the 693 daily measurements available, in 105 daily measurements the PM_{10} concentrations surpassed the maximum threshold value (50μg/m^3) (Fig.2). The minimum concentration (50.33 μg/m^3) during this 105-days timeframe was recorded on 31st August 2009, whereas the maximum (168.26μg/m^3) on 21st December 2010. This maximum value is three times higher than the maximum threshold value. During summers the PM_{10} concentrations are the lowest, probably because in this period the amount of precipitation reaches the annual maximum and the atmosphere is washed-out. Winter concentrations tend to be higher due to the emissions added by domestic heating in the city.

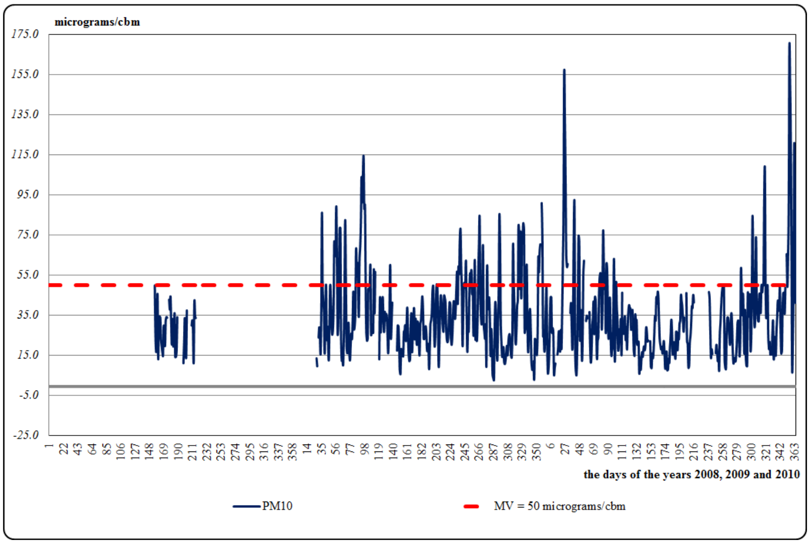

Figure 2 The evolution of PM_{10} concentrations in Suceava City during 2008-2010.

The main sources of PM emissions in Suceava City are located in relation to the SV2 station as follows:

- At a distance of approx. 2000 m, on the SSE direction, the large combustion plant S.C. TERMICA S.A. Suceava is located (thermoelectric plant on coal). It conforms to the legal requirements regarding the threshold values of the emissions.
- At approx. 1000 m west the combustion plants of S.C. AMBRO S.A. (natural gas central heating, respectively wood waste) and S.C. MOLDOMEX S.R.L. Suceava (sawdust central heating) are positioned.
- The hazardous waste incineration plant that belongs to S.C, MONDECO S.R.L. Suceava is situated at approx. 1300 m south-west of the SV2 station.
- The outskirts of Suceava City, i.e. the residential areas of Ițcani and Burdujeni, immediately around SV2 station which mostly use the firewood for individual heating (Fig. 3) (APM SV, 2009; 2010)

Other important pollution sources are represented by the solid waste landfill of Suceava, located on the right bank of Suceava River (Mihăilă et al., 2013) and the road traffic.

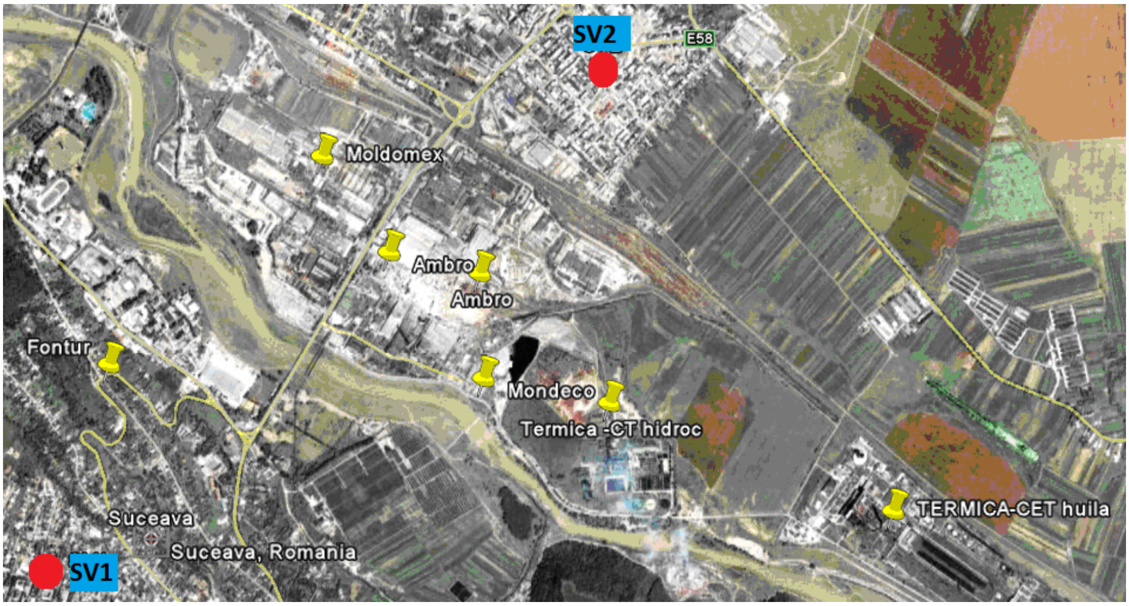

Figure 3 The main sources of emissions in Suceava City in relation to the SV1 and SV2 monitoring stations (red dot).

Based on our data, the maximum threshold value of PM_{10} concentration was exceeded in 15% of cases in the measured period (693 days). These exceedances (105 cases) were mainly distributed in the cold season (69%), whereas the warm season accounted only for 31%. This was a solid argument for inferring that at least between 2008 and 2010 the concentrations coarse particulate matter raised a real problem on urban air quality in Suceava City. Hence we tried to determine the causalities of these concentrations, and of their spatial and temporal dynamics (primarily dependent on the emission sources) in which the climatic factors were shown to play a major role. We further noticed a seasonality of the maximum threshold value. During the cold season, when the thermoelectric power plant CET is powered on, and intense fuel burning starts in the industrial area of Suceava City, 69% of cases with exceedances of the maximum threshold value are recorded. The largest proportion of exceedance cases (34%) were recorded in winter (Fig. 4). Most of the daily exceedances of PM_{10} concentrations (94 of 105) ranged between 50 and 100µg/m^3 (Fig. 5).

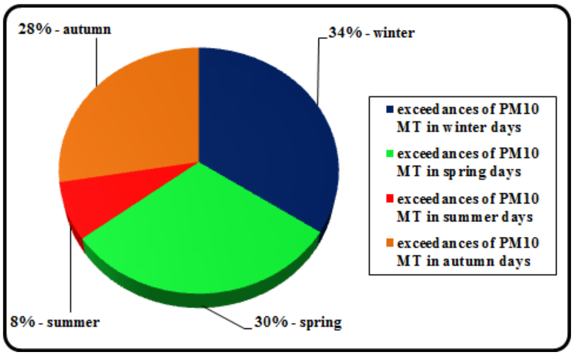

Figure 4 The seasonal percentage distribution of exceedances of the maximum threshold value (MT) of the PM_{10} concentrations.

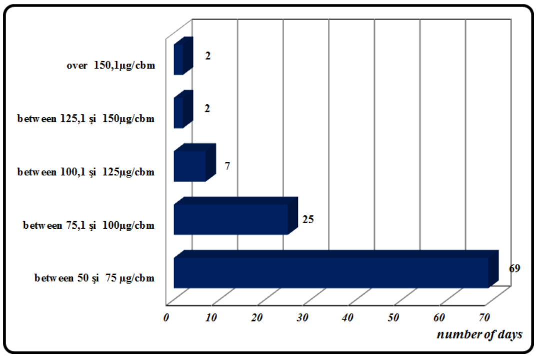

Figure 5 The number of days with MT exceedances of PM_{10} concentrations spread over different concentration ranges of PM_{10}.

4.2. Relationships between PM_{10} concentrations and selected meteorological parameters

Some elements, meteo-climatic phenomena or processes (temperature and thermal stratification of the air, wind, precipitation, air humidity and cloudiness, etc.) have an important role in fostering the dispersion or stagnation of pollution in the atmosphere (Tănasă, 2011). We hereby show the individual relations built between such parameters and PM10 concentration dynamics in our study area, based on the monitoring data available.

Influences exerted by temperature on PM_{10} concentrations

Analyzing the dependence between the high PM_{10} concentrations and the temperature recorded in our study area we could not observe a direct, strong and clear relationship between the two variables (Figs 6 and 7). However we can identify an inverse relation between the two variables, with sharp increases of PM_{10} concentration which correspond to temperature drops (Fig. 6).

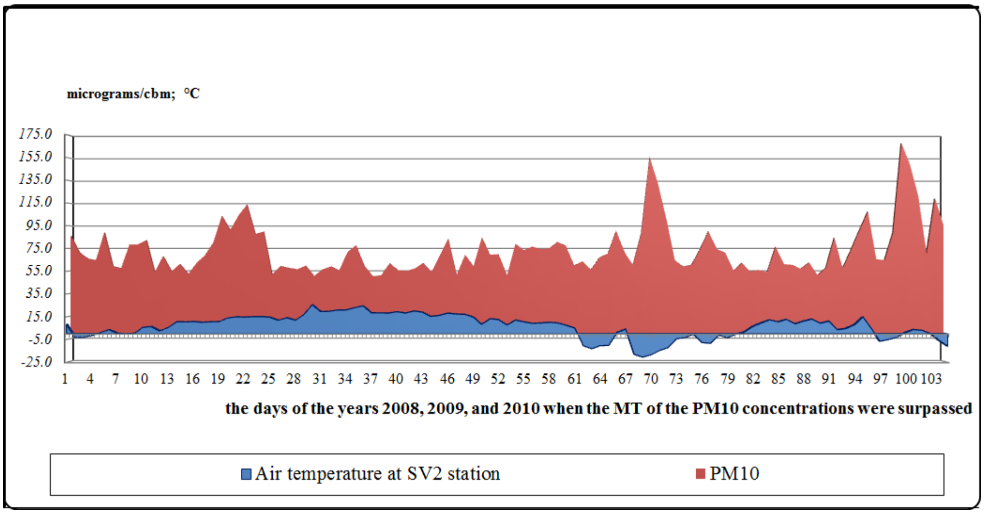

Figure 6 Parallel evolution of PM_{10} concentrations and air temperature in the days when the maximum threshold value of the PM_{10} concentrations were surpassed.

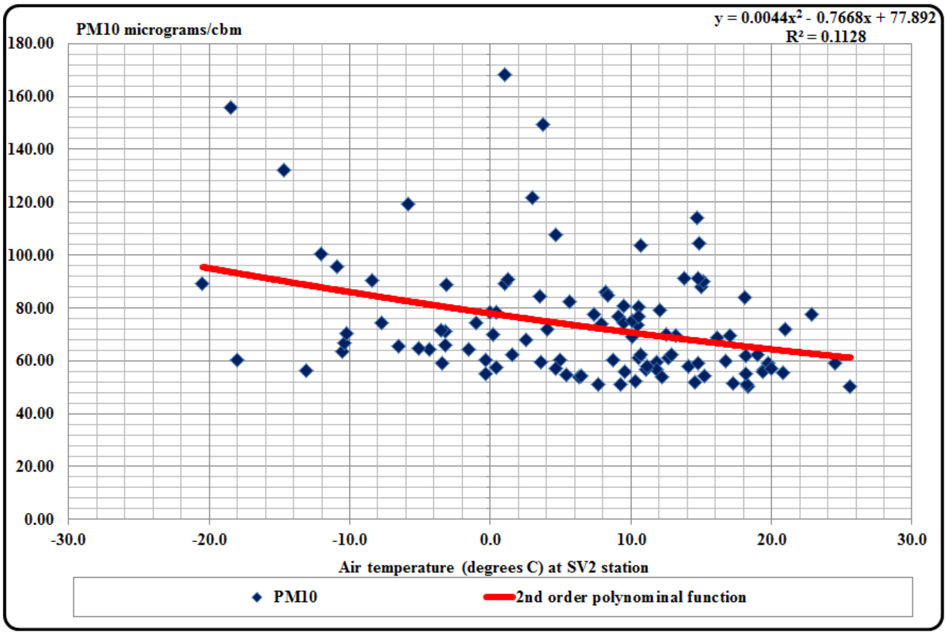

Figure 7 Graphical relationships between air temperature and PM_{10} concentrations for the exceedances days.

Hence, air temperature decrease appears to favor the persistence of PM_{10} in the atmosphere. Similar results for high PM_{10} concentrations in the atmosphere and their relation with temperature were found in other location, for much wider urban areas such as Athens (Grivas et al., 2004) and Leipzig (Engler et al., 2012).

Temperature inversions and their effect on PM_{10}

The thermal stratification reverses have been shown to favor high concentrations of PM_{10} in the atmosphere (Giri et al., 2008). In the lower area of Suceava, during night and in the cold season weak and moderate temperature inversions occur with an annual frequency of 20-25% (Tănasă, 2011.

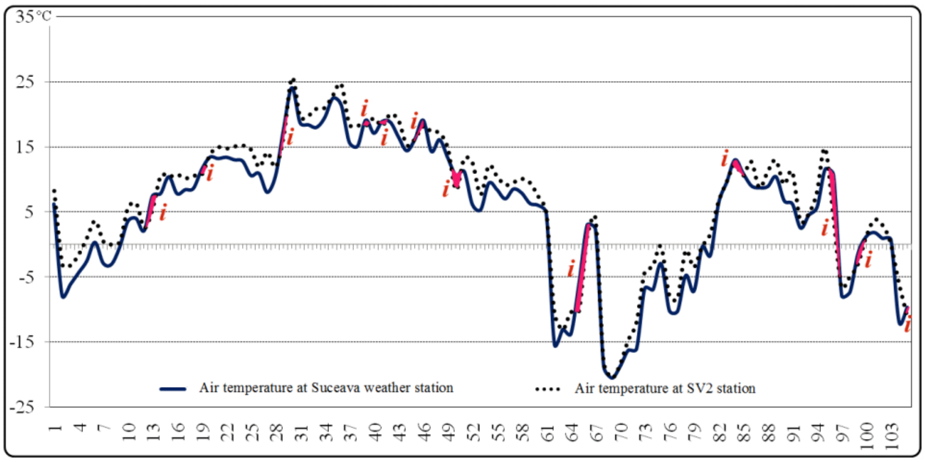

Figure 8 The air temperature evolution at Suceava weather station and SV2 station in the days with exceedances of MT of the PM_{10} concentrations. (The intervals with temperature inversions are marked in red (*i*)).

Inversion situations have previously been related to high concentrations of particulates in west European cities (e.g. Engler et al., 2012). Air temperature data from Suceava weather station (352 m a.s.l.) and SV2 station (289 m a.s.l.) also illustrate the occurrence of temperature inversions during the analyzed period.

However, the days with temperature inversions identified here are based on daily thermal values and not on hourly thermal values. Moreover, our database also includes the days of the warm season (usually without inversions). This may partly influence the relationships statistically established between the temperature inversions and the high concentrations of PM_{10} and consequently lead to a statistically less significant relation. Even under these circumstances, we found that in Suceava City, 17.15% of the cases with exceedances of the maximum threshold value of PM_{10} concentrations occurred during temperature inversions. Consequently, an increase in duration and frequency of the temperature inversions in the area may cause a subsequent increase in PM_{10} concentration, which in turn can create additional health problems for the population.

The influence of baric field dynamics on PM_{10} concentration

An obvious relation can be observed between baric configurations and PM_{10} concentrations (Fig. 9). The high pressure circulation that induces atmospheric stability favors the maintaining of PM_{10} in the atmosphere. In 75 of the 105 days in which the maximum threshold value of PM_{10} concentrations was surpassed, the high pressure systems dominated the local and regional baric configuration, which in turn likely facilitated the persistence of this fraction in the atmosphere of the Suceava City. Similar findings, depicting the influence of local baric formations on PM_{10} concentration dynamics were reported for other locations in northern and south-eastern Europe (Gdansk City - Bielawska et al. 2014; Istanbul - Unal et al. 2011).

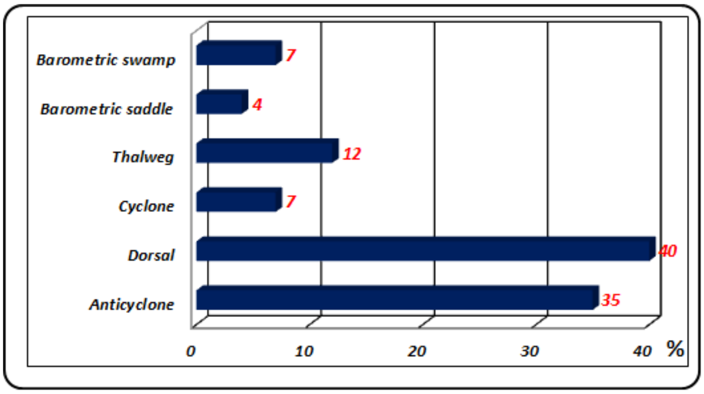

Figure 9 Relationship between the baric formations and the elevated concentrations of PM_{10} in Suceava City. The number of days with exceedances of PM_{10} concentrations is shown in red.

Relative humidity and rainfall in relation to PM_{10} concentrations

Our data point to a weak relationship between the high concentrations of PM_{10} and the relative air humidity (Fig. 10). This relationship is better expressed when we analyze the frequency of the number of cases / days with exceedances of PM_{10} maximum threshold value for different value scales of air humidity. Firstly, we observe that neither dry (f under 50%) nor high humidity days (over 80% f) favor high PM_{10} concentrations. Rather the days with an average or normal humidity (84 days) are the most favorable for the life cycle of PM_{10}. This outcome differs from that obtained for PM_{10} at other locations in Europe (e.g. Giri et al. 2008), indicating that the influence of relative humidity on PM_{10} concentrations shows enhanced spatial and likely temporal variability.

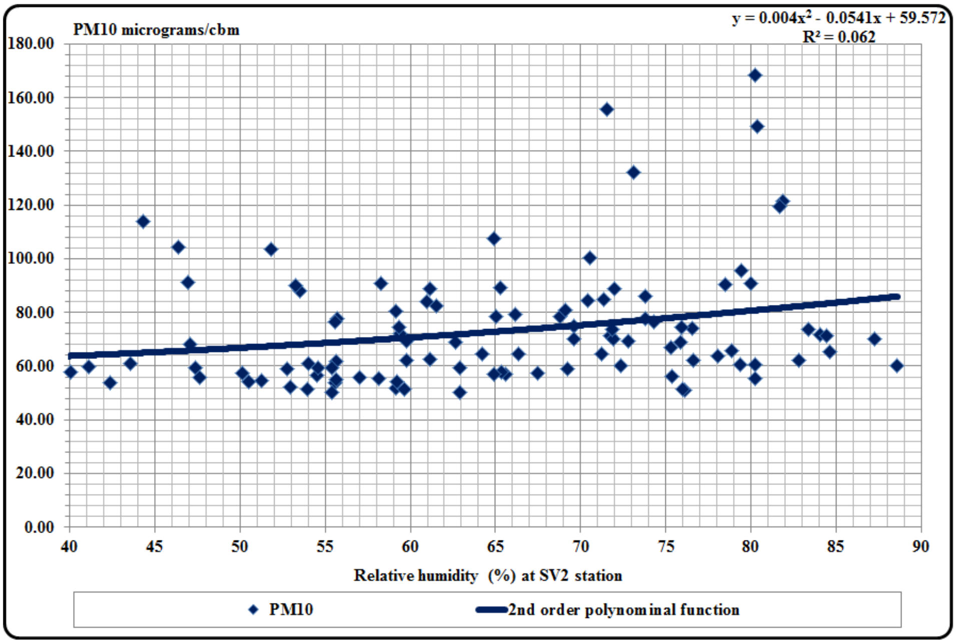

Figure 10 Graphical relationship between relative air humidity and PM_{10} concentrations in the days with exceedances of the maximum threshold value of the PM_{10} concentrations.

Precipitation was generally shown to have an essential impact on PM_{10} concentrations due to the wash-out effect (Giri et al., 2008). As regards our study area, in the 105 days when the MT of the PM_{10} concentration was exceeded, the cumulated amount of precipitation was only 15 mm. Rainfall was extremely scarce (Fig.11), since measured quantities were obtained only in 8% of the target days (daily maxima for the 8 days with rainfall was only 4.2 mm). The precipitations were absent in 92% of the cases with PM_{10} exceedances, which basically illustrates the dominant influence of this parameter on particulate matter concentration.

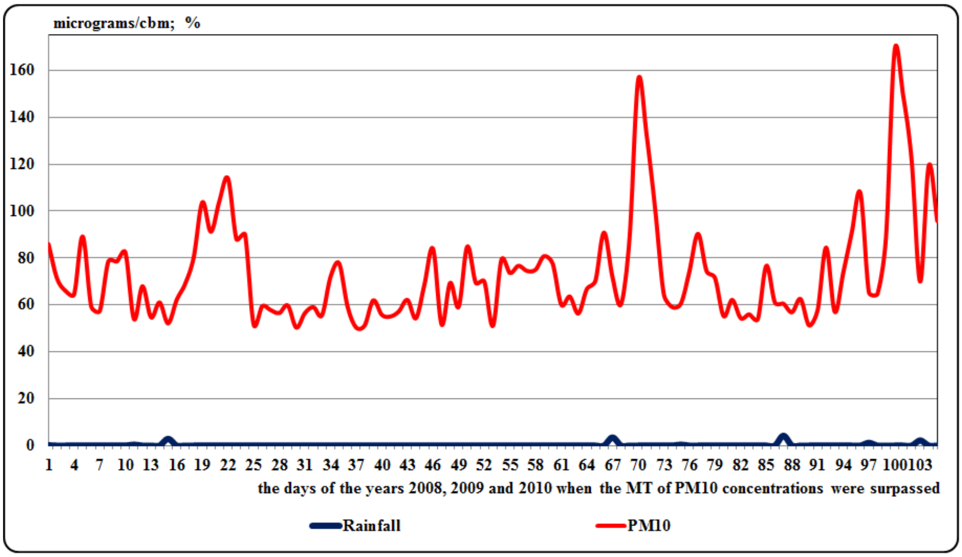

Figure 11 The evolution of the PM_{10} concentrations and rainfall in the days with exceedances of the PM_{10} maximum threshold value.

This outcome is also illustrated by other studies. For example, Rost et al. (2009) highlighted that the absence of precipitation lead to comparatively high PM_{10} levels, particularly in winter, in four cities of the South-Western Germany.

Influences exerted by nebulosity and sunshine duration

Based on our data, an atmosphere loaded with PM_{10} is one with average cloudiness. As such, the cloudy days appear the most favorable for the exceedances of the PM_{10} maximum threshold value. This comes to reinforce previous findings which have shown that atmospheric stability favors the maintaining of PM_{10} in the atmosphere (Galindo et al., 2011). The increase of cloudiness was mainly found to be highly related to the increase of particulate matter episodic events in mining areas (e.g. Lokman et al., 2008).

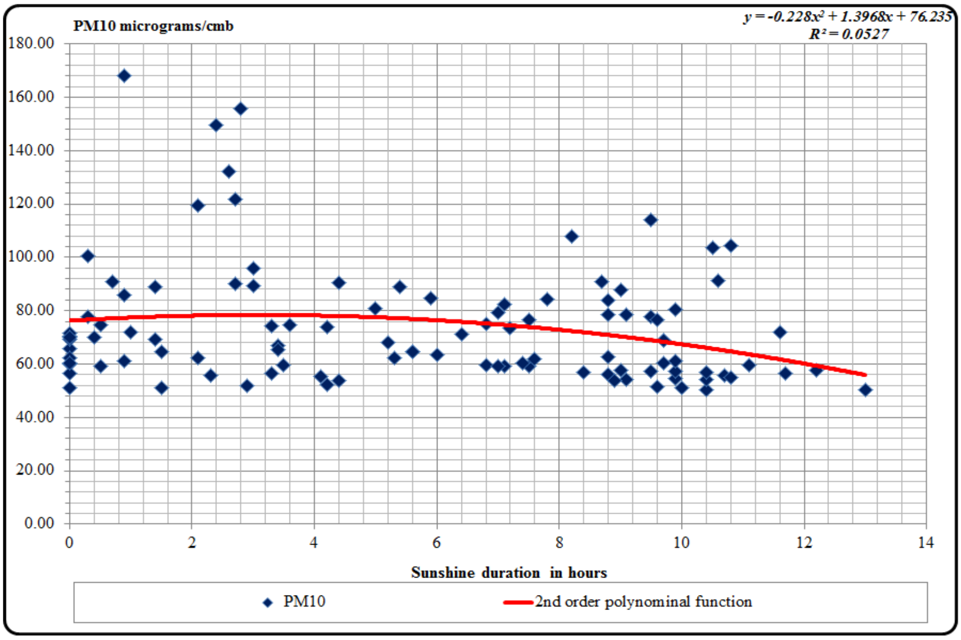

Figure 12 Graphical relationship between sunshine duration and PM_{10} concentrations in the days with exceedances of the maximum threshold value of the PM_{10} concentrations.

Between sunshine duration and the exceedances of the maximum threshold value of PM_{10} concentrations the correlations appear weak, but not inexistent. The increasing maximum sunshine duration corresponds to a slight decrease in the number of cases with exceedances of the maximum threshold value of the PM_{10} concentrations. The decreasing trend is emphasized for the days with more than 11 hours of solar radiance (Fig. 12).

Wind direction and speed

Our data show that, during the 105 days with exceedances, the calm atmospheric days (wind speed < 0.1m/s in 54 days) and days with light wind breeze (wind speed between 0.1 and 1m/s in 51 days) prevailed. PM_{10} thus concentrates in the atmosphere at low wind speeds (Fig. 13) or in situations of atmospheric calm. High wind speeds favor the dispersion of atmospheric pollutants and reduce PM concentrations, while low wind speeds allow pollution levels to rise. This outcome was obtained for PM_{10} at others locations (Chaloulakou et a. 2003, Galindo et al. 2011, Bielawska et al. 2014) and generally shows a clear, strong and inverse relation between these two variables.

In Suceava City the dominant wind directions are NW (27.1%) and SE (10.3%). Higher PM_{10} levels were recorded when winds prevailed from the SE and ESE sectors, likely because the large combustion plant (TERMICA) is situated in this direction. Similarly, lower particulate matter concentration levels were observed during strong northerly flows.

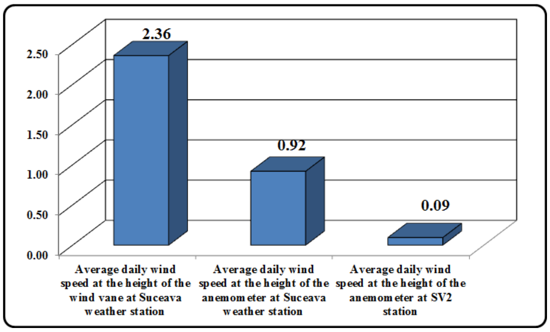

Figure 13 Average wind speed at Suceava weather station (at 10 m – wind vane and 2 m - anemometer) and SV2 station (at 2m high - anemometer) during those 105 days with exceedances of the PM_{10} MT.

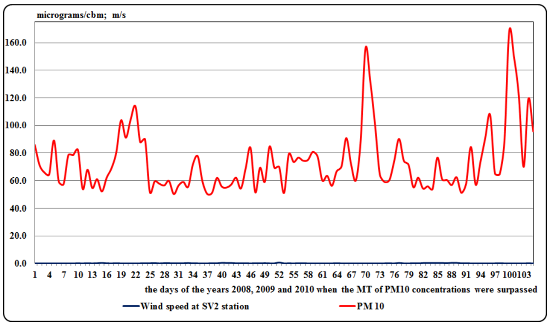

Figure 14 The evolution of the PM_{10} concentrations and wind speed in the days with exceedances of the PM_{10} MT.

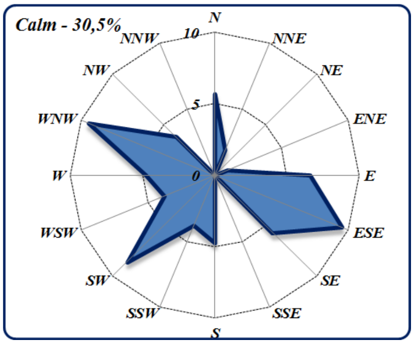

Figure 15 Wind direction and absolute calm frequency at SV2 station during the 105 days with exceedances.

In the 105 days with PM_{10} exceedances the atmospheric calm accounted for 30,5% of the time (Fig.15) and the dominant wind directions were WNW, SW and ESE. Moreover, winds with very low speed brought (sources marked on the map from figure 2) quantities of PM_{10} from the pollution sources located in the industrial area (AMBRO, TERMICA, MOLDOMEX, etc.).

4.3. General relations between PM_{10} concentrations and selected meteorological parameters

In order to illustrate the main relationships between our analyzed meteorological parameters and the variations of PM_{10} concentration, we applied a principal component analysis on all numerical data (Fig. 16).

Based on the results obtained for the first two principal components (PC1 and PC2), which explain over 60% of the total variance induced by our variables, complex underlying relationships could be detected. Hence, the PM_{10} concentrations appear negatively and strongly correlated with the average and maximum wind speed and precipitation in 60% of cases. In other words, our results clearly show that at high wind speeds and precipitation amounts, the concentrations of PM_{10} in the atmosphere of Suceava City decrease considerably. The overall influence of other parameters, such as humidity, nebulosity and temperature, appears less important. This, corroborated with our analysis for individual parameters (Figs 7, 10 and 12), suggests that their effects on PM_{10} concentrations manifest more subtly, at certain values, which should be identified and investigated more detailed.

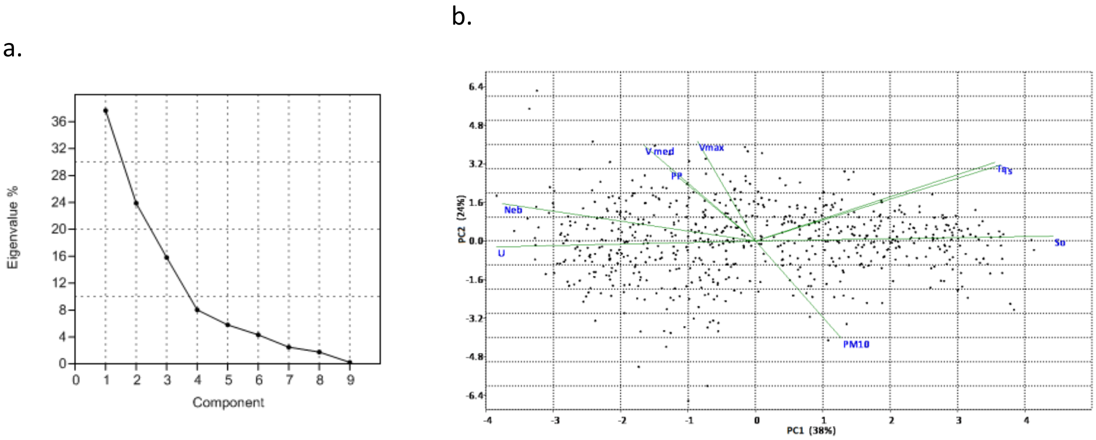

Figure 16 Screen plot (a) and scatter plot (b) of principal component analysis (PCA). The first axis (PC1) explains 38% of variance and the second axis (PC2) accounts for 24%. The variables introduced in the analysis are denominated as follows: Ta - air temperature, Ts - soil temperature, U - relative humidity, Neb - nebulosity, So - sunshine duration, Vmed - average wind speed, Vmax - maximum wind speed, PP - precipitation.

According to our data, we assume that the ideal conditions for occurrence of exceedances of the PM_{10} maximum threshold concentration in Suceava City are as follows:

- Air temperature is below 10°C for more than three consecutive days, in which case the heating plants start to produce thermal energy.
- Situations of thermal inversions, particularly along the Suceava River valley.
- The air relative humidity is normal (51-80%) (84 of the cases of exceedances occurred during normal conditions of relative humidity).
- Cloudy days (nebulosity between 2.1 and 7.9 tenths).
- The days with atmospheric calm and low wind speed (in 51 of 54 cases exceedances of the PM_{10} concentrations MT were recorded).
- The wind that blows from the main pollution sources towards residential areas (ENE, WNW, SW, S, N directions).
- The lack of precipitations which generally wash the atmosphere (only in 8 of the 105 days in which the MT of the PM_{10} concentrations were surpassed, precipitation was recorded, but in extremely low amounts.

5. Conclusions

The main objective of this study was to assess the influence of selected meteorological conditions on the concentrations of PM_{10} in the urban, hilly area of Suceava City (North-Eastern Romania), during the recent period (2008-2010). An average total of 105 days with daily PM_{10} concentrations exceeding the threshold value were found between January 2008 and December 2010. Wind speed and precipitation amounts were identified as the dominant parameters which influence PM_{10} concentrations, while the effect of temperature, humidity or nebulosity appeared more subtle. This highlights that meteorological conditions have a great influence on dispersion of air pollutants and should be taken into consideration in health risk assessment plans. The exceedences of PM_{10} threshold concentrations were more frequent in winter, when particular matter tends to concentrate in higher amounts due to the emissions added by domestic heating in the Suceava City. Noteworthy relationships were observed between PM_{10} and atmospheric pressure and wind speed. The lowest PM_{10} concentrations are found in the low-atmospheric pressure regime, which induces turbulence, whereas the most elevated are observed during high-pressure conditions and low wind speeds. In 75 of the 105 days in which the MT of the PM_{10} concentrations was surpassed the high pressure systems facilitate the persistence of this particulate matter fraction in the Suceava atmosphere. The meteorological conditions can be critical in limiting dilution and thus in enhancing accumulation of the particles and thus influence the situations of exceedances. As such, a combined effort of local and national stakeholders, based on quantitative, local data, appears as the most effective and sustainable solution for prevention and limitations of the negative effects of particular matter concentration increases.

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References

Bielawska M., Wardencki W. 2014. Influence of Meteorological Conditions on PM_{10} Concentration in Gdańsk. *5th International Conference on Environmental Science and Technology*. IACSIT Press, Singapore.

Chaloulakou A., Kassomenos P., Spyrellis N., Demokritou P., Koutrakis P. 2003. Measurements of PM_{10} and $PM_{2.5}$ particle concentrations in Athens, Greece. *Atmospheric Environment* **37**: 649-660.

Cocerhan C. 2012. *Bazinul râului Suceava pe teritoriul României – valorificarea potențialului turistic.* Ph.D. thesis, Universitatea București, România.

Constantin D.M., Cofas E. 2014. The influence of nebulosity on the air pollution in the area of Slatina city. *International Journal of Academic Research in Environment and Geography* **1 (1):** 7-14.

Engler C., Birmili W. Spindler G., Wiedensohler A. 2012. Analysis of exceedances in the daily PM_{10} mass concentration (50 $\mu g m^{-3}$) at a roadside station in Leipzig, Germany**.** *Atmos. Chem. Phys*., **12**: 10107-10123.

Galindo N., Varea M., Gil-Moltó J., Yubero E., Nicolás J. 2011. The Influence of Meteorology on Particulate Matter Concentrations at an Urban Mediterranean Location. J*ournal of Water Air and Soil Pollution* **215:** 365-372.

Giri D., Krishna Murthy V., Adhikary, P.R. 2008. The Influence of Meteorological Conditions on PM_{10} Concentrations in Kathmandu Valley. *Int. J. Environ. Res*., **2** (**1**): 49-60.

Grivas G., Chaloulakou A., Samara C., Spyrellis N. 2004. Spatial and temporal variation of PM_{10} mass concentrations within the greater area of Athens, Greece**.** *Journal of Water Air and Soil Pollution* **158**: 357-371.

Hammer Ø., Harper D. A. T., Ryan P. D., 2001. PAST - Palaeontological statistics. http://www.uv.es/~pardomv/pe/2001_1/past/pastprog/past.pdf, accessed at 30.10.2015.

Houthuijs D., Breugelmans O., Hoekb G., Vaskovic E., Mih!alikov!ad E., Pastuszkae J.S., Jirikf V., Sachelarescug S., Lolovah D., Meliefsteb K., Uzunovah E., Marinescu C., Volff J., de Leeuwa F, van de Wiela H., Fletcheri T., Lebreta E., Brunekreefb B.2011. PM10 and PM2.5 concentrations in Central and Eastern Europe: results from the Cesar study. *Atmospheric Environment* **35**: 2757-2771

Iorga G., Balaceanu Raicu C., Stefan S.2015. Annual air pollution level of major primary pollutants in Greater Area of Bucharest. *Atmospheric Pollution Research* **6**: 824-834

Lokman H. T., Pinar S., Omar A., Ferhat K., Gürdal T. 2008. Effect of meteorological parameters on fine and coarse particulate matter mass concentration in a coal-mining area in Zonguldak, Turkey, *Journal of the Air & Waste Management Association*, **58** (**4)**: 543-552.

Makra L., Ionel I, Csépe Z., Matyasovszky I., Lontis N., Popescu F., Sümeghy Z.2013. The role of different transport modes on urban PM10 levels in Bucharest and Szeged, Central Europe. Buletinul AGIR, Supliment 1.

Mihăilă D., Diţoiu Valeria, Bistricean Petrut-Ionel.2013. The current state of municipal solid waste landfills in Suceava county and their impact on water and soil. *Georeview* **22**: 106-128.

Proorocu M., Odagiu A., Oroian I.G., Ciuiu G., Dan V. 2014.Particulate matter status in Romanian urban areas: PM10 pollution levels in Bucharest. *Environmental Engineering and Management Journal,* **13 (12):** 3115-3122

Rost J., Holst T., Sähn E., Klingner M., Anke K., Ahrens D., Mayer H. 2009. Variability of PM_{10} concentrations dependent on meteorological conditions. *Int. J. Environment and Pollution,* **36**, Nos. 1/2/3.

Tănasă I. 2011. *Clima Podișului Sucevei – fenomene de risc, implicații asupra dezvoltării durabile.* Ph.D. thesis, Universitatea Stefan cel Mare Suceava, România.

Unal Y. S., Toros H., Deniz A., Incecik S. 2011. Influence of meteorological factors and emission sources on spatial and temporal variations of PM_{10} concentrations in Istanbul metropolitan area, *Atmospheric Environment* **45**: 5504-5513.

World Health Organization. 2003. *Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide*, Report on a WHO Working Group, Bonn, Germany.

World Health Organization. 2013. *Review of evidence on health aspects of air pollution – REVIHAAP Project*, Technical Report, World Health Organization Regional Office for Europe, Copenhagen.

*** E.E.A. Report. 2013. *Air quality in Europe - 2013 report.*

*** A. P. M. Suceava.*The 2008-2010 Yearbooks on Environmental State*.

*** Official Journal of the European Union. 2008. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0050:en:NOT, accessed 25.10.2015

*** *SR EN 12341/2002* - Calitatea aerului. Determinarea fracţiei PM 10 sub formă de pulberi în suspensie. Metodă şi proceduri de încercare in situ pentru demonstrarea echivalenţei cu metoda de măsurare de referinţă. (*SR EN 12341/2002* - Air quality - Determination of the PM 10 fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods).