Journal of Environmental Science and Engineering A 4 (2015) 567-577
doi:10.17265/2162-5298/2015.11.002

Ambient Air-Quality Impact as a Determinant External Factor of the Exposome in Cacica Area, Romania

Sorin Ioan Stratulat[1, 2, 3], Marius-Mihai Cazacu[3, 4] and Adrian Timofte[3, 5]

1. Department of Medicine and Pharmacy "Gr. T. Popa", Faculty of Medicine and Dental Medicine, Iasi 700100, Romania

2. Clinic of Rehabilitation, Physical Medicine and Balneo-climatology, C.F. Clinic Hospital Garabet Ibraileanu, Iasi 700506, Romania

3. Atmosphere Optics, Spectroscopy and Lasers Laboratory, Faculty of Physics, "Alexandru Ioan Cuza" University of Iasi, Iasi 700506, Romania

4. Department of Physics, Gheorghe Asachi Technical University of Iasi, Iasi 700050, Romania

5. Regional Forecast Center Bacau, National Meteorological Administration, Bacau 600274, Romania

Abstract: Some geographic regions induce beneficial effects on health status. The world health organization is interested in analyzing this type of climate area in order to establish a network health status. Understanding the parameters of this type of climate creates the prerequisites for further research to define their influence on humans, as an external determining factor of the exposome. Supported by historic and medical epidemiology data, the Cacica area, Roman has beneficial effects on human health. This climatic natural area will be characterized by monitoring their parameters. Thus, they will be rigorously defined and considered of major influence in the exposome. Air quality measurements were made and the local meteorological parameters were monitored. These were correlated with LIDAR data. The atmospheric layers have been evidenced and a possible scenario for the elimination of the pollutant aerosols has been created, in case, the area suffers contamination during a certain season. The analyzed area shows as climatic characteristics both the absence of pollutant factors and the natural structure of the geo-system. The characterization of this area associated with the special terrain (the through), involves the introduction of new local development directions: education, ecology and economy.

Key words: Aerosols, climate-therapy, environmental monitoring, exposome.

1.Introduction

"Cum modo frigoribus premimur, modo solvimur aestu Aere non certo, corpora languor habet", "When we are cold, when we are hot, the drowsiness takes hold of our bodies in lack of air" [1].

That is why Hippocrates considers the air to be the author and the conductor of all the accidents that take place in human bodies. Of course, if people compare the changes that the air causes in the human body with the ones caused by food or other unnatural elements, they will see that the changes due to air are far more violent than any other [1].

Ramazzini also presented the complex influence of the air quality factor on human health, social organization, food, daily activities, with the specification—"The Beotian air had, in the past, a very bad reputation, but the one in Croton was considered to be very healthy, thus, the saying healthier than Croton. Where the air is cleaner, the people must be living longer, because the air does not affect only human skin, but also enters bodies. This made Hippocrates say: the air is the master and the leader of everything that takes place inside human bodies" [1].

As Lioy [2] said in his paper—in 1987, the first National Research Council Committee on Exposure met to discuss inhalation exposure to air pollution. Today, the research perspectives lead to the development of new interdisciplinary connections. Thus, the body exposure to the external factors must

Corresponding author: Sorin Ioan Stratulat, Ph.D., research fields: physical medicine and atmosphere optics.

be clearly defined both in contamination conditions and in minimum contamination conditions (as it should be in a “clean” balneo-therapeutic area) [3-6].

The exposome is a measure of the effects of life-long environmental exposures on health. The exposome development in a person’s life is the result of the exposure to all kinds of toxic chemical substances. The internal body environment reflects the contamination effect (from air, water and food) and its reaction with the toxic chemical substances produced by the body in pathologic processes (inflammation, oxidative stress, lipid peroxidase, microbiological flora and gut) [2, 7-9].

The absence of pollutant factors and of meteorological parameters variations with adverse effects on the human body will be reflected in the internal body’s environmental analysis in the exposome [10].

The climatotherapy procedures are part of the balneo-climatic therapy and the physical climatic factors affect the human body.

For this study, it chooses a balneo-therapeutic area known not to exercise a negative influence on human health, as is shown by historical and medical data.

The Cacica site in the north-eastern region of Romania was founded at the beginning of the 17th century by the Austro-Hungarian empire when exploitation of the salt mine began. The geological structure allowed the continuation of this activity until nowadays with modern means of salt extraction, without any ecologically harmful effects.

The brine (salt in solution) extracted from underground is gravitationally transported from the brine reservoir located at the well’s mouth, through a pipe above ground over a distance of about 4.7 kilometers, to the preparation chamber in Pârteştii de Jos ($47^o64'19''$ N latitude, $25^o96'08''$ E longitude). Here, the raw brine is subjected to a purging treatment, which is necessary to making the evaporation-recrystallization process more effective. After purging, the brine is directed to the evaporation installation. The evaporation process is based on the principle of the “multiple effect in vacuum”. The drying process is done in a hot air dryer and the resulting salt is taken to the classification-packing section [11].

From an administrative point of view, Cacica is located in the center of Suceava county, approximately 40 kilometers from Suceava, at the intersection of county roads Păltinoasa DJ209-Solca with Cacica DJ1781-Todireşti-Suceava. In terms of geographic coordinates, Cacica area is located $47^o34'$-$47^o41'$ N latitude and $25^o47'$-$25^o56'$ E longitude. In terms of morphology, the topography area belongs to the Moldavian Sub-Carpathians, respectively to the homonym depression (Cacica), located at the contact of the eastern Carpathians and the plateau area of the above mentioned sub-Carpathians [12, 13].

In the northern sector of the Volovaț-Roman plateau, the interfluve was sectioned by transversal valleys, which, through erosion activity, led to the appearance of a series of spurs with wide and flat crests. These spurs continue to the east without any noticeable height differences, the piedmont accumulation in the lower part of the Bucovina’s Obcina Mare being interrupted by the sub-Carpathian depressions Marginea, Solca and Cacica [13]. This is how the hilly terrain of Cacica resulted, bordered at north-west by Custura peak (973 meters) and at south-east by Ciungi massif (629 meters). The lowest altitude of the Cacica depression in the area of interest, in the southeastern part of the commune, is 380 meters [12].

From a geological point of view, as shown in Fig. 1, in Cacica area, the predominant deposits are from the upper Miocene, from the Helvetian (he) and the Badenian (to) respectively. In the geological development, these deposits came into existence in the area of Molasse contained by the outer limit of the flysch and the peri-Carpathian line, identified from the north border of Romania down to the Dâmbovița valley [14].

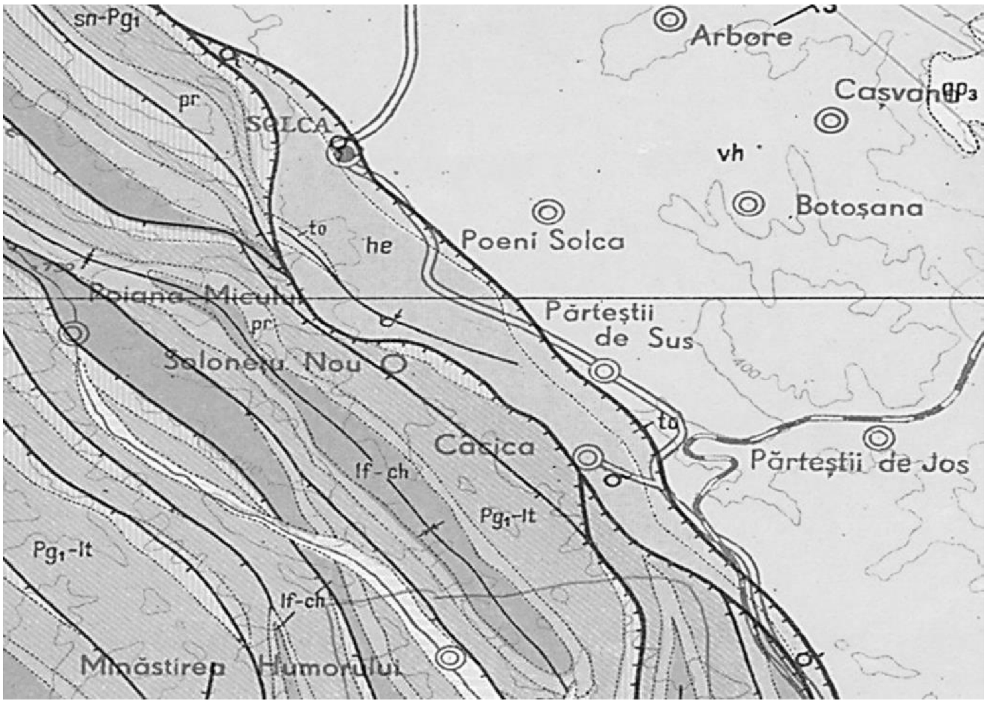

Fig. 1 Geological map of Solca area-Cacica, 1:200000 [14].

In the northern part, where the area of interest is located, the area of Molasa is very narrow up to the Moldova valley, having a width between 300 meters and 3,000 meters.

The Miocene of the area of Molasa formed the filling of the marginal depression and is represented by very heterogeneous deposits, including clays, evaporates, carbonated sandstone and conglomerates etc..

During the middle Miocene, the Helvetian deposits of calcareous limestone, thick gray marl and clay which reach over 1,300 m were formed. At the base of the upper Miocene, in the Badenian, after the marine phase at the beginning, the movement of the stearic phase determined a slight elevation of the area of Molasa and the installation of a lagoon system. Thus, very heterogeneous deposits appeared, most of them consisting of marl, grey clay, soft sandstone and salt, a series known in literature as the upper salt formation of Miocene.

This study tried to demonstrate, by specific measurements, that the area of Cacica salt mine in Suceava county, Romania, is beneficial for human health. Nor does it have a negative influence on the local exposome.

2. Material and Methods

Air-quality measurements were made and the local meteorological parameters were monitored. These were correlated with LIDAR data. The atmospheric layers have been evidenced and a possible scenario for the elimination of the pollutant aerosols has been created, in case the area suffers a contamination during a certain season. The area analyzed shows climatic features, including both the absence of pollutant factors and the natural structure of the geo-system. The characterization of this area associated with the special terrain (the through), involves the improvements of new directions in regional development: education, ecology and economy.

After the analysis of the geographical location and the terrain, one can see the Cacica area is naturally protected. Concerning the air quality, this study takes into account the closest possible pollution sources. As will be shown later, the main wind direction is NNW-SSE. It can be seen that the Cacica area has slim chances of being contaminated with polluted air, at least at ground level, from Suceava city area. The main pollution sources of Suceava's air are the intense car traffic, thermal power plants, the energy and the furniture industries, which specified in the last report of the national environmental protection agency [15].

During the period between 13 July and 28 October 2011, measurements of the PM 10 concentrations in Cacica region were made. During these measurements, there were also recorded values of some meteorological parameters: wind speed, wind direction and temperature etc..

For this analysis, continuously recorded data over 108 days was used. This period includes the transition from the warm season to the cold one. It is allowed for different situations for the correct data interpretation, such as rainy, sunny, dry, warmer or colder days.

The concentrations of particulate matter were measured using a dust track aerosol monitor model 8520, which has the possibility of determining the concentrations of particulate matter with dimensions between 0.1 μm and 10 μm [16]. They refer to the PM 10 type particulate matter because the extended exposure to particles with 10 μm dimensions has a negative impact on the health status of the exposed subjects, especially on the respiratory system [17, 18].

Variation of a meteorological parameter for a short time was taken into account (considering that five minutes of mediation is sufficient). The particulate matter concentrations remain constant. For a clear prominence of the impact of a high or low particulate matter concentration, a mediation time of 10 minutes was preferred [19]. The meteorological parameters were monitored using a LSI LASTEM station which contains the following sensors and characteristics: wind sensor, temperature sensor, relative humidity sensor and pressure sensor.

Due to the topography of the Cacica area, the trough shape (Fig. 2), the way in which the atmospheric layers in the lower troposphere (to an altitude of 800 meters MSL) are influenced by the terrain's shape, may have a direct and immediate implication over the exposome, both by the variation of the aerosol concentration distributions (natural or anthropogenic) and by the interactions between the local meteorological parameters [20, 21]. The studies were completed by the monitoring of the tropospheric aerosol distribution in altitude and the determination of the atmospheric levels with a LIDAR system. The MicroLIDAR system is based on an emitter (pulsed laser-7.2 kHz, with an energy of 3 μJ at 532 nm, pulse duration 0.6 ns), a beam expander with a geometric factor of 20 and a Ritchey-Chretien model LX200GPS telescope. The detection optics was optimized for the 532 nm elastic channel. The acquisition module allowed the LIDAR signal to have a spatial resolution of 7.5 m, a temporal resolution of 10 seconds to 5 minutes, up to 5-7 km in height [22, 23].

The measuring devices were close to the main road of the settlement and at a distance of about 300 meters from the salt mine. During this period, in the vicinity of the monitoring point, reconstruction work was taking place in an old school dating from the Austro-Hungarian period. Because of the special terrain in which the studied zone is located, the fumigation phenomena and the valley breeze (day/night) was taken into consideration.

3. Results and Discussion

Among the 108 daily measured medium concentrations, 27 have surpassed the daily limit value for human health protection, according to the order 592/2002 (50 $\mu g/m^3$—do not exceed more than 35 times in a year) [24].

Therefore, for the PM 10 indicator, the daily limit value for human health protection has been exceeded and the annual limit value has not been reached.

The atmospheric precipitations were slightly over the climatological norms in July and under the norm from August-October (Figs. 3 and 4).

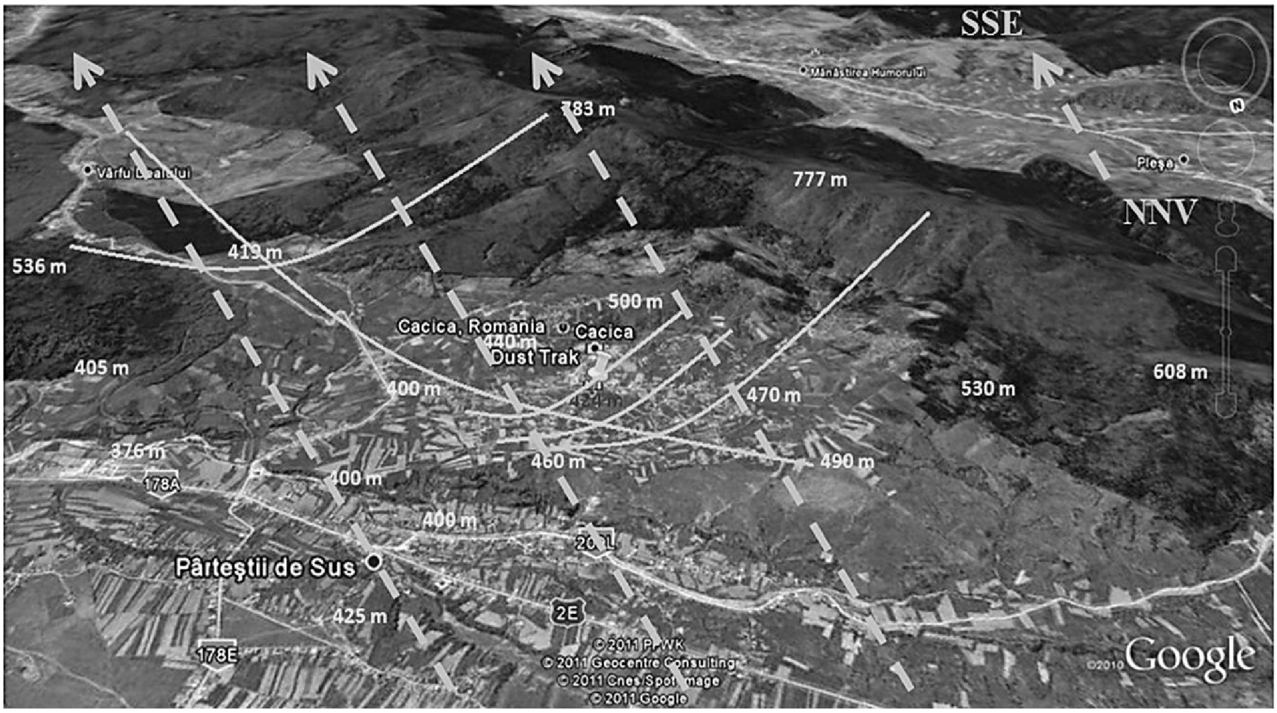

Fig. 2 Cacica and surroundings, representation of predominant (dashed lines) wind directions and topography illustration (solid lines) of the "trough".

In terms of the wind direction and intensity data, it can be observed that the wind speed in the studied area is low, the medium speed is 0-2 m/s, in 92% of the cases, the wind speed was between 0 m/s and 2 m/s, in 7% of the cases, the wind speed was between 2 m/s and 4 m/s and only in 1% of the cases the wind speed was higher than 4 m/s. The predominant wind direction is from NNV towards SSE (Fig. 5).

The temperature inversions from valleys differ significantly from the inversions from plains, firstly because the valleys have strong daytime heating and cooling cycles.

The increased heating of the atmosphere of a valley during daytime and the amplification of the cooling during night-time is due to the valley's volume effect [25].

In this respect, the average maximum and minimum temperatures of the area studied were compared with the average maximum and minimum temperatures at the weather station in Suceava, which is part of the National Meteorological Administration (NAM). Indeed, the maximum and minimum average temperatures for Cacica are higher and lower than the minimum and average temperatures for Suceava (Fig. 6).

The influence of the valley-volume effect as well as the temperature inversions has a direct impact on the structure of the atmospheric boundary layer. As it is known, the atmospheric boundary layer represents a part of the atmosphere that is directly influenced by the surface earth phenomena, at a time scale from a few minutes to several hours [26, 27]. The monitoring of an area such as Cacica also implies the observation of the atmospheric layers, especially in the lower troposphere, because solutions may be found if the area suffers contamination of the air with pollutants from the surrounding environment. Due to the special terrain of the area, it is imperative that the air quality is maintained. So, for the monitoring of the aerosol distribution with the altitude, the above-mentioned eye safe MicroLIDAR system was used. This unitary overlap system function can be varied from 50 meters to 250 meters. A complementary analysis of the LIDAR's range corrected signal time series was sufficient and is presented in Fig. 7.

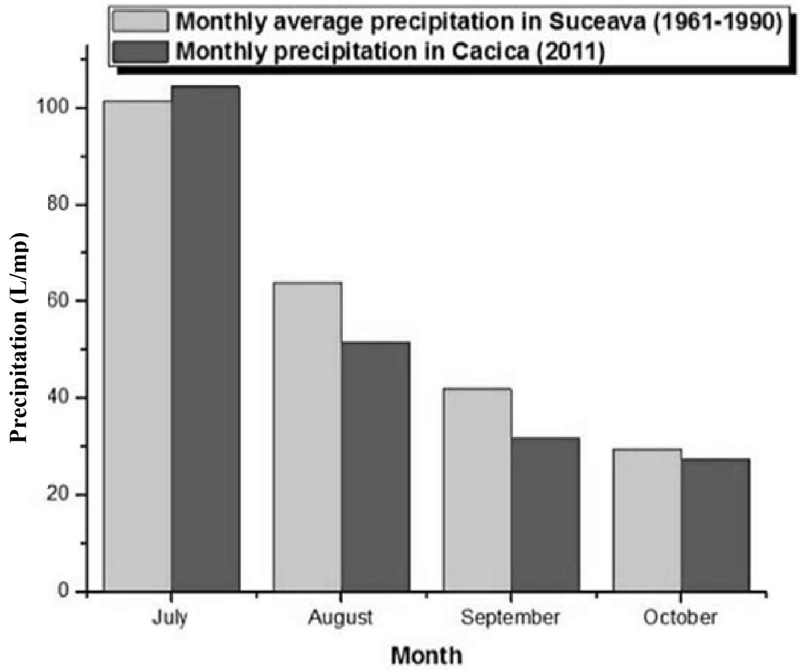

Fig. 3 Comparison between the medium monthly rainfall quantities recorded in Suceava and the monthly rainfall quantities of Cacica.

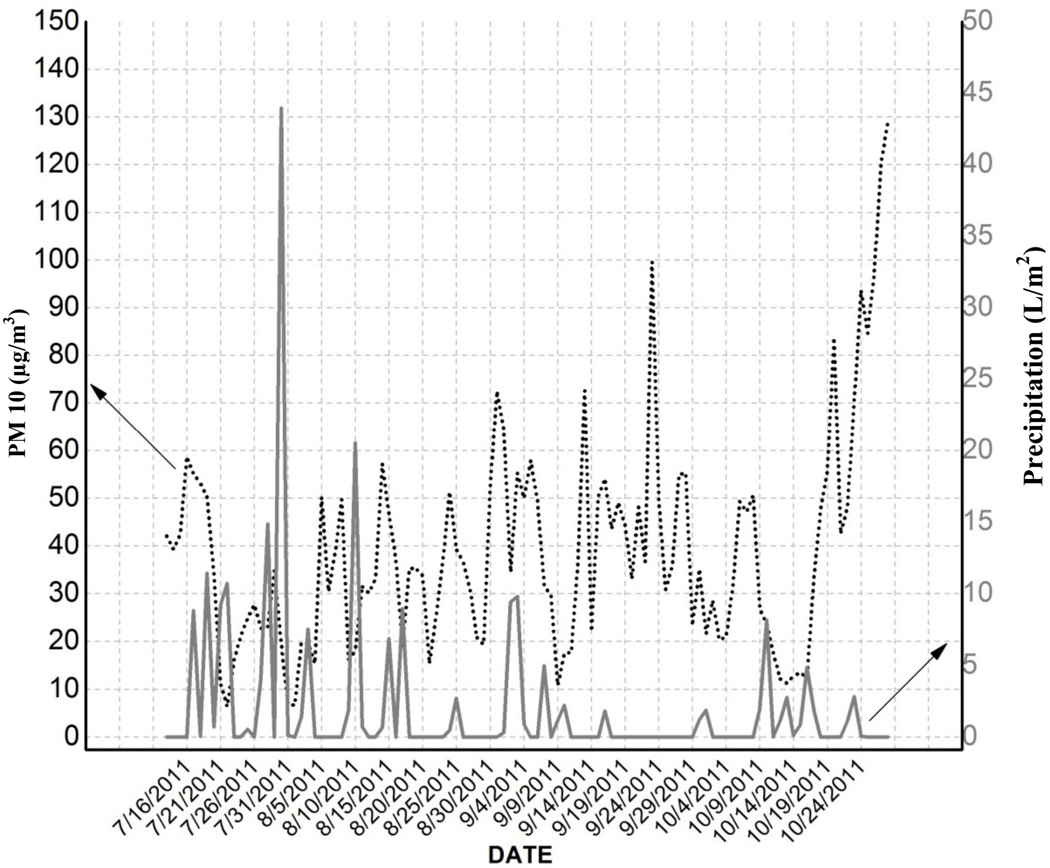

Fig. 4 Comparison between the rainfall quantities recorded near Cacica and the PM 10 concentrations recorded in the center of the location.

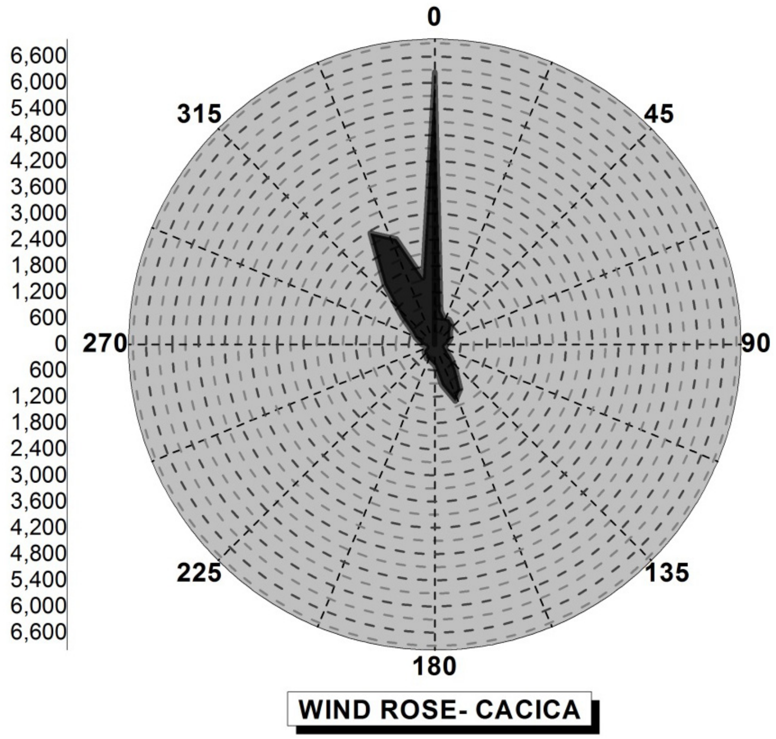

Fig. 5 Wind rose representation.

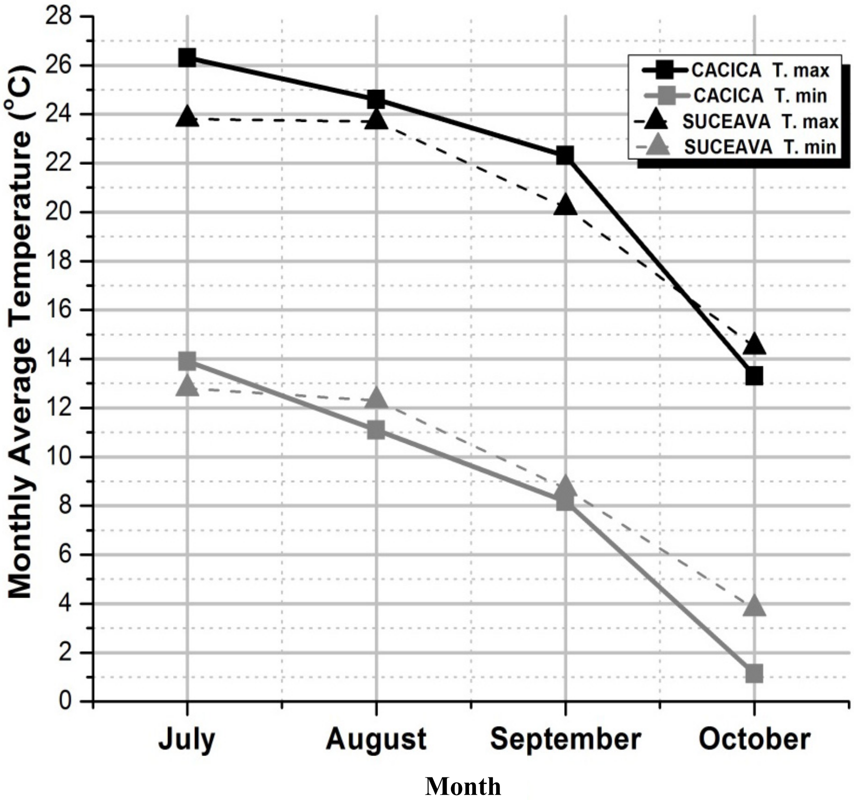

Fig. 6 Comparison between the average maximum and minimum temperatures in Cacica area and the average maximum and minimum temperatures in Suceava.

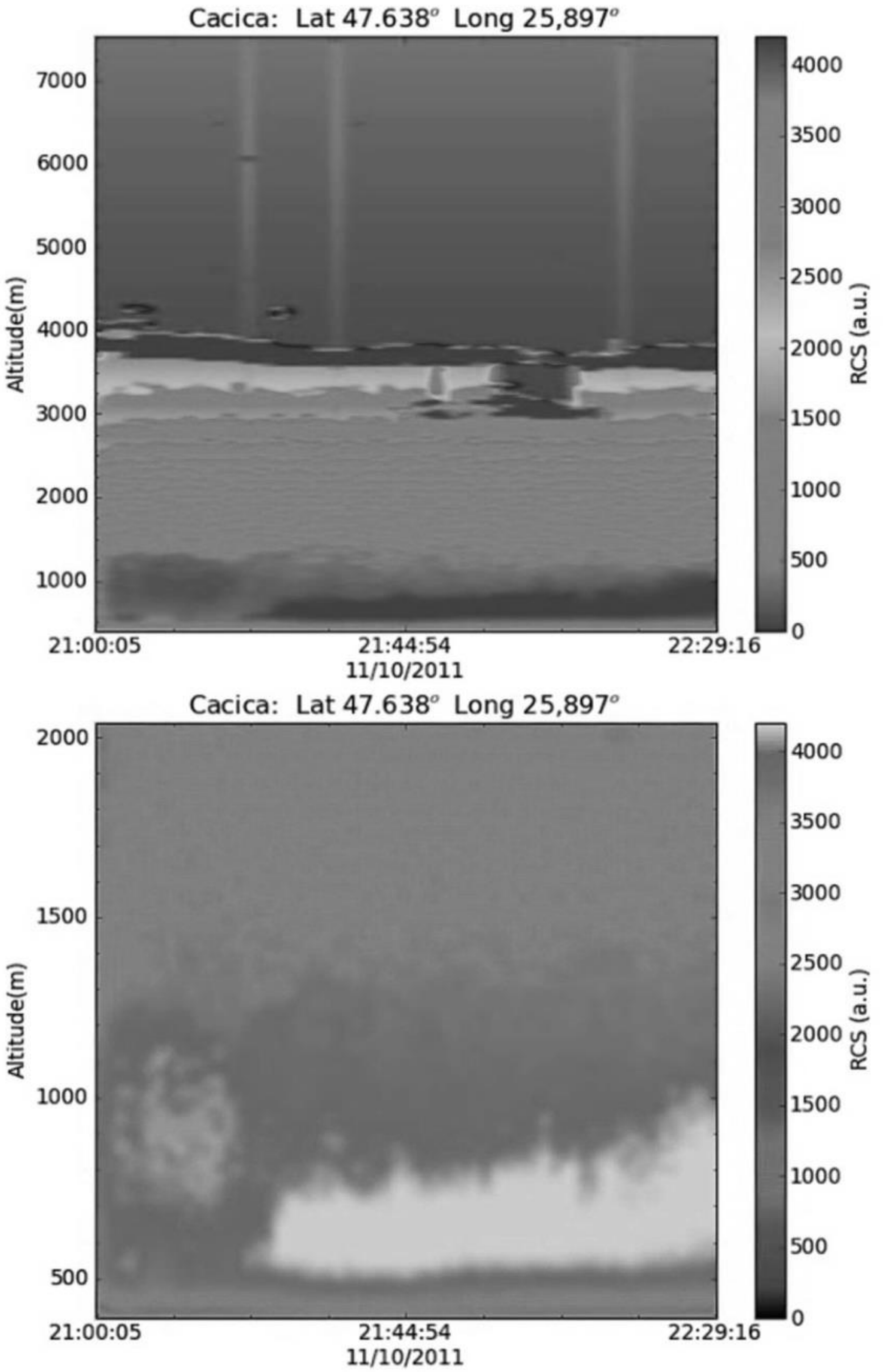

Fig. 7 LIDAR data: representation of Range Corrected Signal (RCS) time series up to 7 km (top) and up to 2 km for highlighting the appearance of aerosols (bottom), spatial resolution: 30 m, temporal resolution 1 min. 11.10.2011—local time.

The bright area below 800 meters shows the backscatter from the aerosol rich layer. The LIDAR measurements showed that between 500 meters and 700 meters, atmospheric inversions took place. Thus, it can be observed an atmospheric layer at approximately constant height (500 m), for one week of measurements. The fact that the altitude was determined at which atmospheric inversions take place, allowed to analyze the dispersion scenarios of the contaminating aerosols by correlating LIDAR data with meteorological and pollution data.

Although one cannot generalize that this inversion is present throughout an entire year, the fact that during the short monitoring period, the transition from the warm season to the cold one took place, allowed highlighting a slight increase in aerosol concentration caused by the local people using heating sources in the evening (based on burning wood and coal) intensively. As shown below, trough the fumigation phenomenon and the valley breeze (day/night), the natural evacuation of the eventually polluted air is possible.

4. Conclusions

The analyzed area is a natural geo-climatic one uninhabited before 1700.

Following the discovery and the beginning of the salt exploitation, the socio-urban structure was:

- Specific to the Austro-Hungarian empire, until 1918, the pollution source in the region consisted of the salt processing technology (which involved wood burning);
- After 1918, the salt exploitation belonged to the kingdom of Romania, with the same salt-processing conditions;
- Between 1945 and 1989, the communist regime partially modernized the salt extraction methods. Without a property deed in the region, however, the urban development stopped;
- From 1989 until today, the development improved with the introduction of eco-friendly salt-extraction technology and the property deeds were passed to the population, following Romania's accession to the European union (with the strict monitoring of the European environmental laws), a possible socio-urban development as a balneo-therapeutic resort was shaped.

During the 300 year-period, the Cacica natural area was characterized by a beneficent influence of the surroundings over human health, associated with the effect of the rich mineral reserves in the soil.

- This study tried, firstly, to scientifically determine if this natural geographic area can have an impact on health status as an external factor of the exposome (determinant) on the exposure from an air quality point of view;
- During the period between July 13th and October 28th 2011, in Cacica area, Suceavacounty, PM 10 concentration measurements were made. At the same time, some meteorological parameters such as precipitation, wind speed and direction and temperature etc. were recorded;
- Among the 108 daily measured average concentrations, 27 exceeded the daily limit value for human health (50 $\mu g/m^3$);
- Most of the time, the wind speed was low (0-2 m/s) and the predominant wind direction was from NNW towards SSE;
- The atmospheric precipitations were under the climatological norms during August-October and the monthly medium temperatures were slightly over the norm.

The special terrain and the fact that during the monitoring period the transition from the warm season to the cold one took place was takes into account.

Knowing the predominant wind direction shown that the area, at least at the ground level, is not affected by urban pollution from Suceava, especially because of the low wind speeds and the special shape of the terrain.

This certifies that the environmental factor of this region induces low levels of organic and inorganic pollutants, the type of air flow and thermal variation have good influence on the human health status as "good air" for the daily life of the inhabitants.

This determining influence factor needs to be correlated in the future with other external factors of exposome and with biological analysis of the local inhabitants, in order to analyze the influence of this natural areal upon their biology.

Acknowledgements

The authors gratefully acknowledge the Romanian Atmospheric Research 3D Observatory (RADO).

References

[1] Ramazzini, B., and Cornaro L. 2009. "The Preserving Art the Princes' Health and the First-Rank People." In *the Preserving Art of the Monastic Health and Religious Benefits of Temperate Life*, edited by Stratulat, I. S., and Cluj Napoca. Romania: Eikon.

[2] Lioy P. J. 2010. "Exposure Science: A View of the Past and Milestones for the Future." *Environmental Health Perspectives* 118: 1081-1090.

[3] Barr, D. B. 2006. "Expanding the Role of Exposure Science in Environmental Health." *Journal of Exposure Science and Environmental Epidemiology* 16: 473.

[4] Franke, A., Reine, R. L., Pratzel, H. G., Franke, T., and Resch, K. L. 2000. "Long-Term Efficacy of Radon Spa Therapy in Rheumatoid Arthritis—A Randomized, Sham-Controlled Study and Follow-Up." *Rheumatology* 39: 894-902.

[5] Lioy, P. J., Lebret, E., Spengler, J., Brauer, M., Buckley, T., and Freeman, N. et al. 2005. "Defining Exposure Science." *Journal of Exposure Analysis and Environmental Epidemiology* 15: 463.

[6] Sheldon, L. S., and Hubal, E. A. C. 2009. "Exposure as Part of a Systems Approach for Assessing Risk." *Environmental Health Perspectives* 117 (8): 1181-1184.

[7] Lioy, P. J., and Rappaport, S. M. 2011. "Exposure Science and the Exposome: An Opportunity for Coherence in the Environmental Health Sciences." *Environmental Health Perspectives* 119 (11): 466-467.

[8] National Institute of Environmental and Health Sciences (NIEHS). 2010. "Superfund Researchers Propose Exposome Paradigm." Accessed December 7, 2015. http://www.niehs.nih.gov/news/newsletter/2010/december/science-superfund.cfm.

[9] National Institute of Environmental and Health Sciences (NIEHS). 2011. "Exposome Pioneer to be Featured at Workshop." Accessed December 7, 2015. http://www.niehs.nih.gov/news/newsletter/2011/december/science-exposome.

[10] Center for Disease Control and Prevention (CDC). 2010. "Exposome and Exposomics: Overview." Accessed December 7, 2015. http://www.cdc.gov/niosh/topics/exposome.

[11] Ionce, A. 2009. "Methods of Reducing the Impact of the Preparation Activity of the Useful Mineral Substances." *Present Environment and Sustainable Development* 3: 9-10.

[12] Bleahu, M., Bradescu, V., and Marinescu, F. 2005. *Romania Geological Nature Reserves*. Bucharest, Romania: Ed. Scaiul.

[13] Mihailescu, V. 1996. *Hills and Plains of Romania*. Bucharest: Editura Stiintifica Tehnica..

[14] National Institute for Research and Development in Tourism-Bucharest (INCDT). 2009. *Pre-feasibility Study of Cacica, Praid and SlanicPrahova Saline Mines about Touristic Rearrangement*. Report Phase 1.

[15] ANPM (National Agency for Environmental Protection). 2010. "Report on Environmental Situation in Suceava County—2010." Accessed December 7, 2015. http://apmsv.anpm.ro/Mediu/raport_privind_starea_mediului_in_romania-15.

[16] Industrie Automation Graz (IAG). 2008. *TSI—Dusttrak, II Aerosol Monitor Theory of Operation Application Note EXPMN-001*, *Guide of Operation*. Graz: IGA.

[17] Bhola, G. R., Lakhani, A., and Balasubramanian, R. 2010. "Air Pollution Monitoring and Source Characterization." In *Air Pollution-Health and Environmental Impacts*, edited by Bhola G. R., Molina, T. L., and Ojha C. S. P. New-York: CRC Press.

[18] Grabow, M. L., Spak, S. N., Holloway, T., Stone, B., Mednick, A. C., and Patz, J. A. 2011. "Air Quality and Exercise-Related Health Benefits for Reduced Car Travel in the Midwestern United States." *Environmental Health Perspectives* 120: 1449-1455.

[19] Cazacu, M. M., Timofte, A., Dimitriu, D., Gurlui, S., and Balin, I. 2011. "Complementary Atmospheric Urban Pollution Studies in the North-East Region of Romania." *Environmental Engineering and Management Journal* 10: 139-145.

[20] Katul, G. G., Finnigan, J., Poggi, D., Leuning, R., and Belcher, S. E. 2006. "The Influence of Hilly Terrain on Canopy-Atmosphere Carbon Dioxide Exchange." *Boundary-Layer Meteorology* 118: 189-216.

[21] Ebi K. L., and McGregor, G. 2008. "Climate Change, Tropospheric Ozone and Particulate Matter, and Health Impacts." *Environmental Health Perspectives* 116 (11): 1449-1455.

[22] Balin, I., Picoulet, G., Balanici, A., Ristori, P., Nicolae, D., and Ristici, V. et al. 2008. "A New MicroLidar for 3D Aerosols Load, Clouds and PBL Dynamics Observations, European Geosciences Union: Geophysical Research Abstracts EGU2008." Accessed December 7, 2015. http://meetings.copernicus.org/www.cosis.net/abstracts/EGU2008/06637/EGU2008-A-06637.pdf.

[23] Unga, F., Cazacu, M. M., Timofte, A., Bostan, D., Mortier, A., and Dimitriu, D. et al. 2013. "Study of Tropospheric Aerosol Types over Iasi, Romania, during the Summer of 2012." *Environmental Engineering and Management Journal* 12 (2): 297-303.

[24] AAQS. 2011. "Law on Ambient Air-Quality No.104 of 15 June 2011, Ambient Air Quality Standards from Monitorul Official No 452." Accessed December 7, 2015. http://mmediu.ro/file/2011-12-29_legislatie_calitate_aer_

legea104din2011calitate%20aer.pdf.

[25] Whiteman, C. D. 2000. *Mountain Meteorology*: *Fundamentals and Applications*. Oxford: Oxford University Press.

[26] Kunz, G. J., De-Leeuw, G., Becker, E., and O'Dowd, C. D. 2002. "Lidar Observations of Atmospheric Boundary Layer Structure and Sea-Spray Aerosol Plumes Generation and Transport at Mace Head, Ireland (PARFORCE Experiment)." *Journal of Geophysical Research* 107: 1-14.

[27] Stull, R. B. 1988. *An Introduction to Boundary Layer Meteorology*. Dordrecht: Kluwer Academic Publishers.