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Changes of the Turda Salt Mine Underground Microclimate Induced by its Rehabilitation and Touristic Exploitation

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Abstract

Saline microclimate is a very important element in the process of speleotherapy used mainly in ameliorating respiratory illnesses. Having one of the best treatment potential among the European countries, many of the Romanian' salt mines can be successfully used in speleotherapy. Moreover, in order to improve the touristic and therapeutic exploitation, Turda Salt Mine was rehabilitated trough a PHARE program. Taking into consideration the possibility that the saline microclimate could be affected by the rehabilitation works and the new exploitation conditions, a series of physico-chemical parameters have been analyzed. The particulate matter of different aerodynamic diameters – PM_1, $PM_{2.5}$ and PM_{10}, and some chemical compounds (CO_2, CO, NO_2, SO_2, CH_4) were monitored in three rehabilitated chambers (Rudolf, Terezia, Ghizela) of Turda Salt Mine during ten months (December 2009 – September 2010). Furthermore, other chemical compounds such as heavy metals, PAH, VOC and formaldehyde have been sampled and analyzed in the laboratory. The obtained results showed that the presence of certain amounts of chemical compounds in the mine's indoor air that could be the consequence of the rehabilitation technology as well as a consequence of the materials that were used there. Furthermore, the high number of tourists led, on the one hand to the increase of the CO_2 concentration and, on the other hand to temperature, humidity, and particulate matter. These variations, on a long term, could have significant negative impact upon the saline microclimate.

Keywords: Turda Salt Mine, saline microclimate, speleotherapy

1. Introduction

Although it was exploited since Roman times, Turda Salt Mine is the result of systematic exploitation starting with 1960. However, after 1932 its importance was weakened by Ocna Mures exploitation [2]. Considering that after the exploitation process, well-conserved underground chambers were formed and counting its scientific, historical and therapeutic value beginning with 1992, Turda Salt Mine was opened to public.

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Periodic rehabilitation works followed that year but major improvement was accomplished between 2008 and 2009, as a result of a PHARE program that aimed to increase the touristic and therapeutic exploitation of Turda's Salt Mine.

Therefore, rehabilitation works (fig.1) included modern facilities like: pieces of furniture made by wood and metal, parquet floor in Ghizela Mine, entertainment facilities (basketball field, golf course and bowling), new Mine entrance, improvement of the electric system, etc. Moreover, all these were designed carefully, in order to avoid affecting the configuration of the chambers.

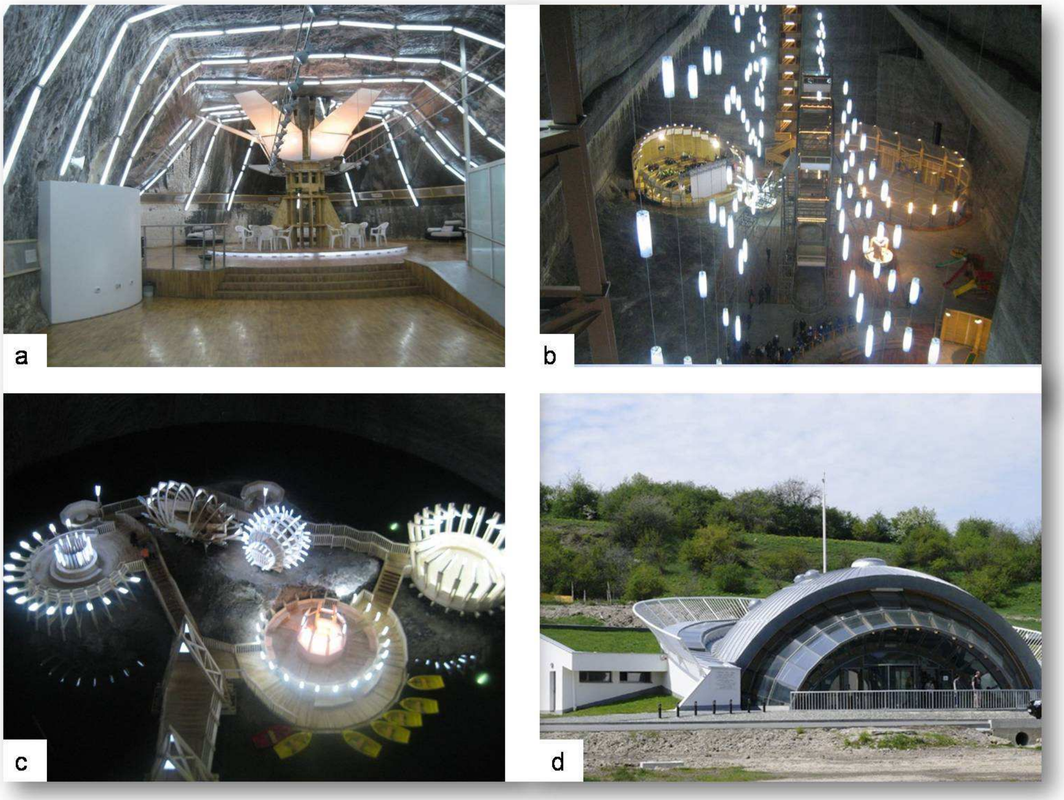

Figure 1. Turda Salt Mine after the rehabilitation works a. Ghizela Mine, b. Rudolf Mine c. Terezia Mine d. new Mine entrance

However, welding processes, creating a new mine entrance, interventions in the ventilation system, using treated wood in chambers rehabilitation and parquet floor, etc., could have had certain influence on microclimatic parameters of Turda Salt Mine.

Therefore, this issue is worth studying, concerning the therapeutic potential of Turda Salt Mine. Furthermore, it is known at an international level that saline microclimate has a therapeutic effect upon respiratory illnesses regarding respiratory diseases and the overall health status.

There are certain characteristics of the microclimate that play an important role in the process of speleotherapy: stable temperature, relative humidity and air velocity, the presence of NaCl dry particulate matter, absence of air pollutants and absence of allergens [3].

Moreover, considering the aspects mentioned above, the study aims to establish if there are microclimatic parameters that have changed, to what degree they have been modified, for how long the changes will persist and what are the implications. Furthermore, the study wants to determine whether there are polluting chemical compounds in the indoor air of Turda Salt Mine, what are the implications of the determined variations and changes and how long it will take for all modified conditions to come back to normal.

2. Material and method

The parameters that were studied in order to establish the changes of the Turda Salt Mine underground microclimate are: temperature, relative humidity, air velocity, particulate matter (PM_1, $PM_{2,5}$, PM_{10} and suspended particulate matter), carbon dioxide, (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), methane (CH_4), polycyclic aromatic hydrocarbons (PAH), heavy metals, volatile organic compounds (VOC) and formaldehyde.

In order to accomplish the aim of the study, some of the microclimatic parameters were determined from the air, through direct reading of the instruments' display screen, while others were sampled and analyzed in the laboratory.

The microclimatic parameters monitoring lasted from December 2009 to September 2010. The values obtained are averages of different time intervals, between 15 and 45 minutes.

The measurements were performed during a 4-season period, inside and outside the salt mine, in order to establish the influence of the natural variations of the outdoor air parameters over the microclimatic changes. Moreover, different phases that take place in the salt mine as a touristic objective have been considered: the period immediately after the rehabilitation works of the salt mine finished (before it has been opened to the public) and also the period when the touristic flux increased continuously.

The measurements and samplings were performed inside Ghizela Mine, Rudolf Mine, Terezia Mine (fig. 2) as well as outdoors. Temperature, relative humidity, air velocity, particulate matter (PM_1, $PM_{2,5}$, PM_{10} and suspended particulate matter), carbon dioxide, (CO_2) were monitored every month and polycyclic aromatic hydrocarbons (PAH), carbon monoxide (CO), nitrogen dioxide, (NO_2), sulfur dioxide (SO_2), methane (CH_4), heavy metals, volatile organic compounds (VOC) and formaldehyde were sampled or determined in certain time intervals.

In order to determine the value of all these parameters from Turda Salt Mine underground microclimate, a series of analytic instruments and laboratory methods were used.

Temperature and relative humidity values were obtained using the Thermohygrometer, 608-H1 model, produced by Testo. The Air Velocity Meter, AIRFLOW™ Model TA430 (TSI) was used to determine air velocity.

The concentration of particulate matter of different sizes: PM_1, $PM_{2.5}$ and PM_{10} were monitored with a direct-reading aerosol monitor - TSI's DustTrak Aerosol Monitor (Model 8520) monthly, over the measurement period (December 2009 – September 2010).

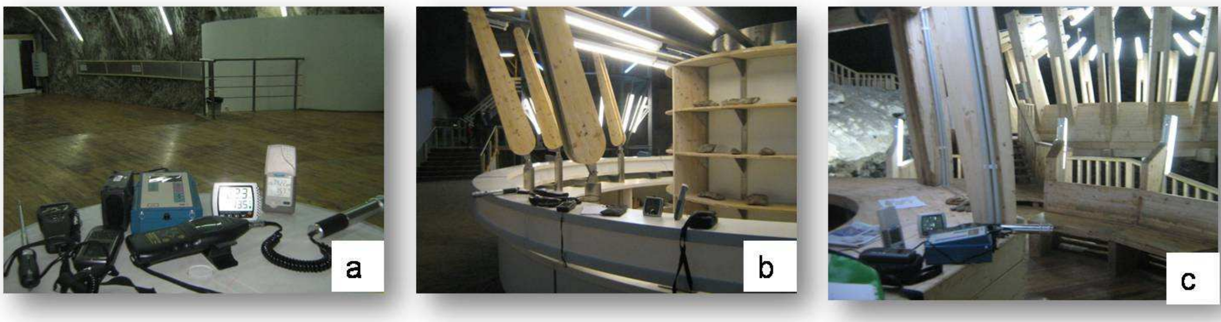

Figure 2. Measurement points in Turda salt Mine **a**. Ghizela Mine **b**. Rudolf Mine **c**. Terezia Mine

The real-time measurements in milligrams per cubic meter (mg/m^3) provided by the laser photometer is based on a 90° light scattering sensor type. They operate by illuminating an aerosol as it passes through an optic chamber (sensing volume) and by measuring the light scattered by all the particles at a given scattering angle relative to the incident beam. As the number of particle increases, the light reaching the detector increases [1].

The concentration of suspended particulate matter was assessed by the Microdust Pro real-time monitor from Casella, USA. The particulate matter concentration is measured using a near-forward angle, light-scattering technique. Infrared light of 880 nm wavelength is projected through the sampling volume where contact with particles causes the light to scatter. The amount of scatter is proportional to the mass concentration and is measured by the photo detector. Carbon dioxide concentration was measured once a month with the Telaire 700 L Carbon Dioxide Monitor that uses the Dual Beam Absorption Infrared™ method, sampling with a diffusion of 50 - 100 ml/min.

Methane concentration was determined at the beginning of the measuring period with the Smart CAT Ex DrägerSensor that is a transducer for measuring partial pressure of flammable gases or vapours in the atmosphere. It functions according to the heat-of-reaction principle.Moreover, NO_2, SO_2, and CO concentrations were analyzed with the OLDHAM MX 21 portable multi-gas monitor.

Polycyclic aromatic hydrocarbons, heavy metals, volatile organic compounds, formaldehyde, CO_2 (also determined by direct reading monitoring) and CO were determined after laboratory analyses were performed. Polycyclic aromatic hydrocarbons and heavy metals were collected by passing the air through a nylon filter of 0.45 μm porosity with an air pump with an air flow of 40 L/min, from Rudolf Mine and Ghizela Mine. The retained Polycyclic aromatic hydrocarbons were then extracted by ultrasonary for 30 minutes in 2 mL of acrylonitrile (ACN) at 60 ^{0}C, using MERCK Darmshtad reactive, from Germany.

The analysis of polycyclic aromatic hydrocarbons was performed by high-performance liquid chromatography (HPLC), using a HPLC Jasco, model 980 equipped with a quaternary pump (JASCO PU–980 MODEL) and a fluorescence detector (JASCO UV–980-975 MODEL) at 254 nm, with a detection limit of 1 ng/m^3 air. Heavy metals were analyzed by flame atomic absorption spectroscopy using a Zenit 700 flame atomic absorption spectroscope purchased from Perkin Elmer (Germany). The mineralization of the samples was performed with nitro muriatic acid, according to the SR ISO 11466.

The quantification of heavy metal was performed using the calibration curves method. Furthermore, air sampling for volatile organic compounds, formaldehyde, CO and CO_2 was done in special sampling bags MIL-B-131H, type 1 class 1, LUNDLOW CORP. The volatile organic compounds were analyzed by gas chromatography coupled with a mass spectrometer (GC-MS QP 2010 Plus).The collected samples were desorbed in 2 ml of methanol and analyzed by GC-MS.

The quantification of target compounds was made by a calibration curve method.

The limit of quantification was 0.06 µg/sample.Considering the importance of carbon dioxide concentrations in indoor air and counting the salt mine indoor air values for this compound, carbon dioxide was determined with a method based on direct reading and also by laboratory analyses after air sampling.

Using the Multigas 1320 Monitor, the concentrations of formaldehyde, carbon monoxide and carbon dioxide were analyzed trough IR photoacoustic spectroscopy, which measures the effect of light absorption upon materials, through acoustic detection. The determinations were made considering the interferences, after blank correction.

3. Results and discussions

In order to analyze the degree in which the saline microclimate was changed by the rehabilitation works taking place at Turda Salt Mine, the mentioned parameters were determined and for the ones that were determined in other studies from 1989 and 1991, the results were compared.The microclimatic study from 1989 was performed by the National Institute of Rehabilitation, Physical Medicine and Balneoclimatology in Bucharest. The determinations were performed in the cold period of the year (28-30 of March) and in the warm period of the year (3-5 of July), in many locations of Tuda Salt Mine. The study from 1991, was performed by the "Iuliu Moldovan" Institute for Public Health from Cluj–Napoca in order to establish weather the Salt Mine is fit for speleotherapy. The microclimatic parameters were analyzed only in the cold period of the year, in March.The results of our study were also compared with the data obtained by the National Institute of Rehabilitation, Physical Medicine and Balneoclimatology from Bucharest in a complex and multidisciplinary study from the spring of 2010.

- **Physical parameters**

The study performed in 1989 was performed in the cold period of the year at temperature of 10.5 $^{\circ}$C at the top of Rudolf Mine and 7.2 $^{\circ}$C at the air shaft. Therefore, in this period there is a difference of 2.5 $^{\circ}$C between different indoor points. By contrast, in the warm period of the year, temperature was a little higher than in the cold period: 9.2°C at the main entrance and 11.2°C at the top of Rudolf Mine. However, the small differences between the two seasons indicate a thermal constancy throughout the year [4]. Moreover, according to the measurements in 1991, temperature in Turda Salt Mine ranges between 11-12^{0}C [5].According to the measurements performed in 2010, temperatures range between 11^{0}C and 12.7 °C with an increasing trend (fig. 3).

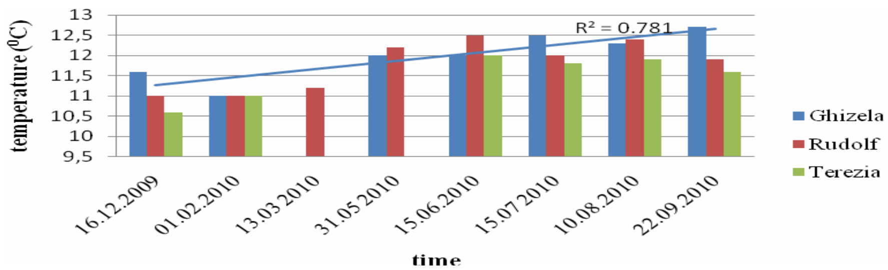

Figure 3. Temperature variations in Turda Salt Mine (December 2009 – September 2010)

Overall, the measurement period, the outdoor temperatures changed between -1.5^{0}C and 36^{0}C but we cannot say that these influence indoor conditions, considering that the highest summer temperatures overlap with the period when Turda Salt Mine had the greatest number of visitors.

Compared to the values from 1989, there is a higher temperature and stronger variations among different locations inside the mine in 2010. Therefore, our study indicates that temperature variations and the general trend of this parameter are clear consequences of the increasing number of visitors. According to the study performed in 1989, the values of relative humidity changed more during the cold period of the year (between 60% and 76%) and less in the warm period – between 72% and 80%. In both cases, relative humidity was higher than outside.

The differences between the measuring points were more obvious in the cold season than in the warm period. This is considered a consequence of the fact that the new entrance of the mine was a work in progress at that time, not a consequence of the outdoor influences. Moreover, in Rudolf Mine, relative humidity remained constant throughout the year [1].

In 1991 relative humidity ranged between 75-79 % in Rudolf Mine and between 73-80 % in Ghizela Mine [6].

The measurements performed between December 2009 and September 2010 indicate relative humidity values between 68% and 74,9% inside the salt mine – between 64.7 and 70% in Ghizela Mine, between 70 and 72.3 % in Rudolf Mine and between 70 and 72.3% in Terezia Mine (fig. 4).

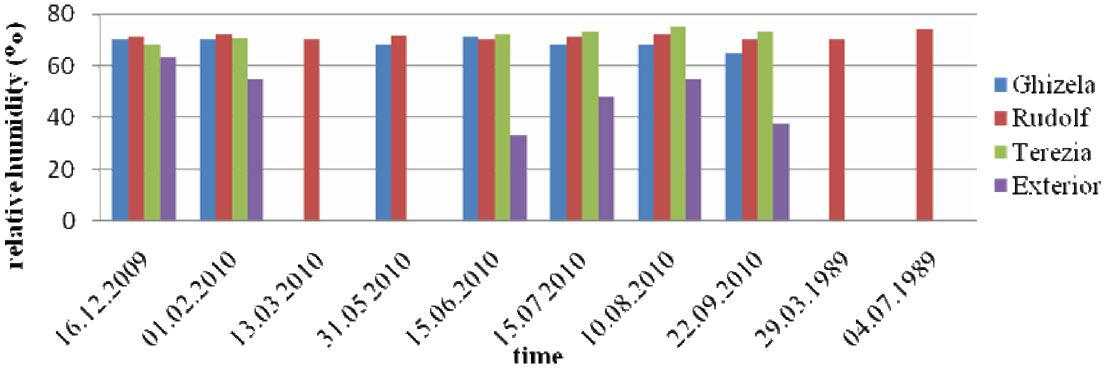

Figure 4. Relative humidity variations in Turda Salt Mine between December 2009 – September 2010 in comparison to the study from 1989

Comparing the data from the different measuring points inside the Mine, one can notice that Terezia Mine has the highest relative humidity and the driest air is in Ghizela Mine. Although current relative humidity variations are similar to the ones registered twenty years ago, relative humidity from Turda Salt Mine has decreased. Moreover, the measurement results show that in August, when Turda Salt Mine was visited by 70.705 persons, the highest number until that time, relative humidity reached the highest value in Rudolf Mine and in Terezia Mine. Therefore, we can consider that this parameter is influenced by the number of visitors that come to Turda Salt Mine. This is not the case for Ghizela Mine because it has shorter visiting hours and a smaller number of tourists.Although when a higher number of visitors were registered, relative humidity was higher, the general trend of this parameter showed a small decrease (fig. 5) that could be due to the influence of the temperature.

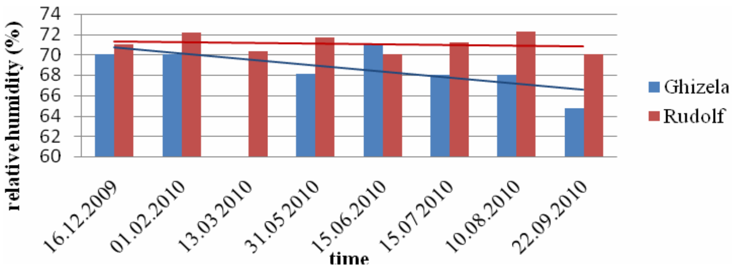

Figure 5. Relative humidity trend in Rudolf Mine and Ghizela Mine

The study performed in 1989 concluded that air velocity was higher at the entrance and near the air shafts. During the cold season, air velocity values varied between 0.3 - 0.4 m/s at the entrance and between 0 - 0.1 m/s for Rudolf Mine. In the warm period, air velocity varied in different chambers of the mine. Generally, at that time, all measurement points registered an air velocity lower than 0.5 m/s, which is the superior limit for indoor comfort. Similarly, in 1991, Turda Salt Mine air velocity had a value of 0.7 m/s at the entrance and 0.3 m/s in Ghizela Mine and 0.02 m/s in Rudolf Mine [1]. According to our measurements the air velocity is also very low and there are cases in which the value is 0 (table 1). Ghizela Mine has a low air velocity but its speed increases when the door is open. Contrary to the situation identified twenty years ago, now, in Rudolf Mine there is a higher air velocity, compared with other mine chambers.

Table 1. Air velocity in Turda Salt Mine (Dec. 2009 – Sept. 2010)

Date	Ghizela Mine	Rudolf Mine	Terezia Mine
16.12.2009	0	< 0.4	< 0.05
01.02.2010	0	0	0
31.05 2010	0	< 0.21	-
15.06.2010	<0.01	<0.15	<0.06
15.07 2010	<0.04	<0.22	<0.04
10.08.2010	<0.01	<0.08	<0.01
22.09.2010		<0.08	<0.02

Similar values referring to Turda Salt Mine microclimatic parameters have been determined by the National Institute of Rehabilitation, Physical Medicine and Balneoclimatology from Bucharest, in the warm period of the year 2010 (table 2). Both studies performed twenty and twenty-one years ago concluded that at that time, temperature, relative humidity and air velocity from Turda Salt Mine were not influenced meaningfully by the outdoor conditions. Our measurements revealed certain changes of these parameters compared to the situation twenty-one years ago:

- higher temperature variations
- increasing trend of temperature
- higher relative humidity variations
- decreasing trend of relative humidity
- low air velocities with

different air velocities in different locations of the mine

Table 2. Values of Turda Salt Mine microclimatic parameters - 30 June – 2 July 2010 (Enache, L., unpublished [2])

Microclimatic parameters / Measurement location	Tempe-rature (^{0}C)	Relative humidity (%)	Air velocity (m/s)
Ghizela Mine	12.6 – 13.3	67 - 70	0
Rudolf Mine	12.0 – 12.6	71 - 74	0
Terezia Mine	11.8 – 12-2	67 - 70	0

Although the changes of these parameters could be attributed in a certain degree to the fact that another mine entrance was created, rehabilitation works do not influence it significantly. Therefore, these variations can be attributed to the increasing number of tourists that is a consequence of the Salt Mine recent rehabilitation works. Therefore, as a consequence of the rehabilitation works, the number of Turda Salt Mine visitors increased significantly from 1965 persons that visited the mine in December 2009, to 70705 persons in August 2010 (fig. 6). Taking into consideration the low air velocity inside the salt mine, a high number of tourists could be the consequence of temperature and relative humidity variations, especially that there is a correlation between the two trends.

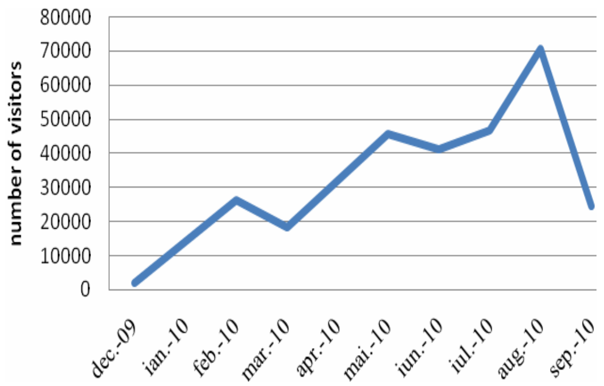

Figure 6. The trend of the number of tourists in Turda Salt Mine

Particle matter measured in the Turda Salt Mine indoor air as a microclimatic marker, refer to different dimension particles with aerodynamic diameter smaller than 1 µm (PM_1), smaller than 2.5 µm ($PM_{2.5}$), smaller than 10 µm (PM_{10}) and total suspended particles that are smaller than 50 µm. According to their dimension, material particles can act as health threats or as beneficent factors in respiratory problems. Therefore, on the one hand, particle matter with certain harmful chemical compounds and smaller than 10 µm, increase the risk of lung illnesses among children under 1 year old, influences the function of lungs, increase asthma and cause respiratory problems [7].On the other hand, increased concentrations of particulate matter with salt (NaCl) composition, like the air from the salt mines, has positive effects upon human health and it is used in speleotherapy. This acts mainly upon the respiratory tract, simulating the secretions, eliminating the viscous secretions, having an inhibiting action upon inflammations and reducing the irritation that causes the caught (Simionca I., et al, unpublished). The effectiveness of the salt aerosols treatment depends also on the size of the particles. Therefore, larger particles with the aerodynamic diameter grater that 10 µm (PM_{10}) are trapped in nasal passages and will deposit in the nasal passages and only the ones smaller than 2.5 µm ($PM_{2.5}$) penetrate the pulmonary region [2].

Moreover, the efficiency of the spleotherapy increases if the NaCl material particles are dry, if the majority of the particles, 99% , are smaller than 3 µm and if they have a concentration range between 5 and 10 mg/m^3 (Chonka, J., unpublished data [2]). According to the study performed in 1989, at that time, particulate matter concentration ranged between 130 - 250/cm^3 with a percent of 80 - 95% for particulate matter smaller than 3 µm that can penetrate the pulmonary region [4]. The value of particulate matter determined from December 2009 and September 2010 ranges between 0.013 mg/m^3 and 0.194 mg/m^3 for PM_{10} , between 0.012 mg/m^3 and 0.188 mg/m^3 for $PM_{2.5}$ and between 0.010 mg/m^3 and 0.179 mg/m^3 for PM_1 (fig. 7). Generally, the highest particulate matter concentration was observed in Rudolf Mine.

Over the year 2010, starting with the end 2009, a gradual decrease of particulate matter concentration of all measured aerodynamic diameter (PM_1, $PM_{2.5}$, and PM_{10}) can be seen in all locations inside the salt mine where they were measured.From the therapeutic point of view, this is not a very benefic trend.

Furthermore, a gradual decrease of the total suspended particles, smaller than 50 µm, was also noticed (fig. 8). This makes the results regarding particulate matter smaller than 10 µm even more credible.

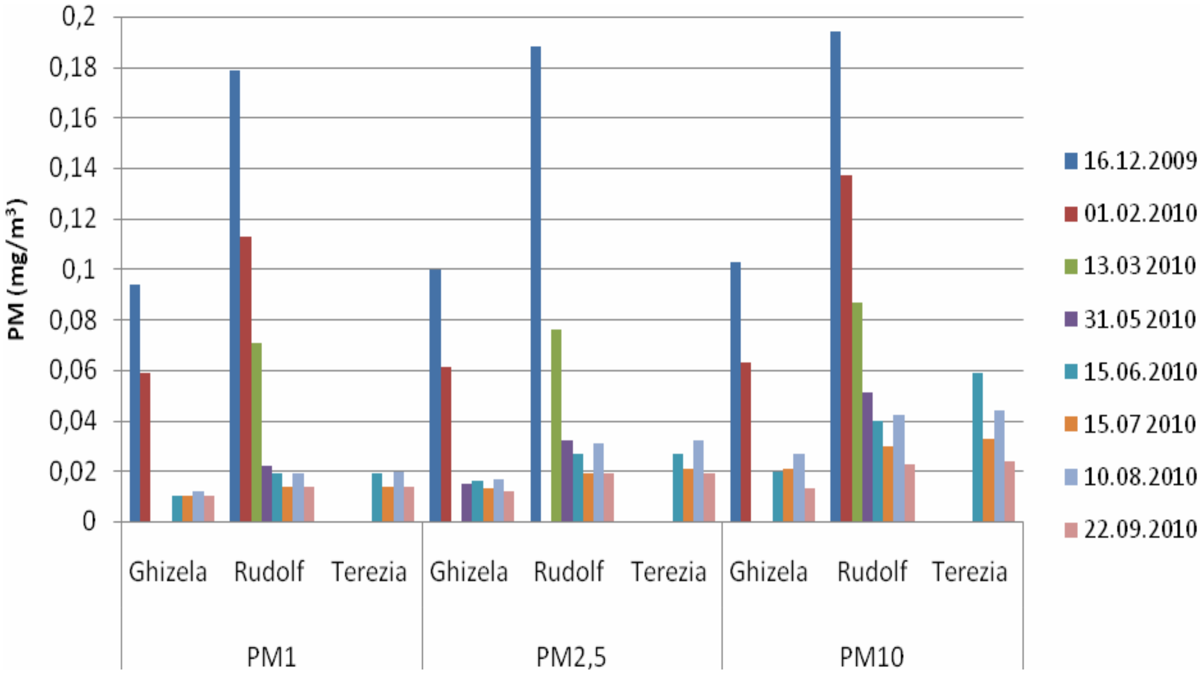

Figure 7. PM_1, $PM_{2.5}$, and PM_{10} variations in Turda Salt Mine

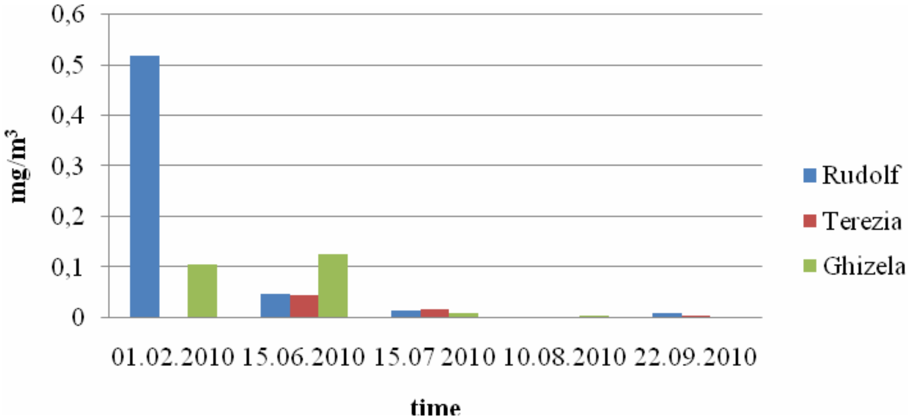

Figure 8. Total suspended particles variations in Turda salt Mine

➢ Chemical parameters

Romanian standards (Government Decision no. 1218/2006) states that carbon dioxide concentration should be under 9000 mg/m^3 in case of an 8 hours exposure at the working place [1].

Between December 2009 and September 2010, carbon dioxide determined inside Turda Salt Mine ranged between 1247.4 mg/m^3 and 18540 mg/m^3 (fig. 9). The concentrations of this gas are dependent on the number of visitors; therefore, the highest values were registered in august when the number of tourists was very high (70705 persons). In addition, August was the months with the highest temperatures.

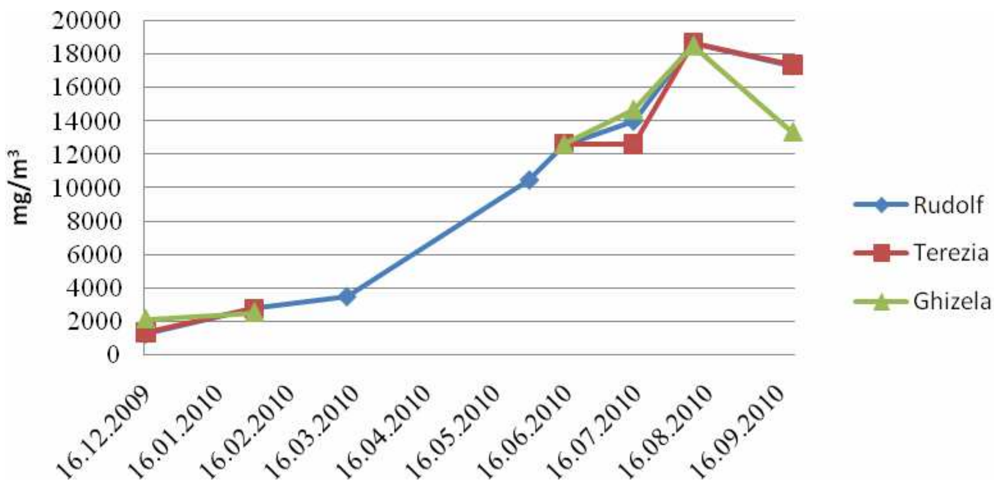

Figure 9. Variations of carbon dioxide concentrations in Turda Salt Mine (December 2009 – September 2010)

By contrast, in 1989 CO_2 concentrations ranged between 724 mg/m^3 and 840 mg/m^3, with a minimum value at the top of Rudolf Mine and a maximum value in Ghizela Mine [4].

The discrepancies are explained by the fact that at the time this study was performed, Turda had few visitors due to the fact that some rehabilitation works were in progress.

Moreover, not even before the rehabilitation works that ended in 2009 were there so many visitors, in comparison to actual statistics.

In a whole year (e.g. 2005) number of persons that visited Turda Salt Mine was very similar to the number of people that visited Turda Salt mine in a month, after the recent rehabilitation works (table 3).

Table 3. Number of persons that visited Turda Salt Mine (2005 - 2009) [6]

Period	2005	2006	2007	2008	2009 (until 01. 09)
Number of persons	43.053	56.197	67.493	63.464	54.537

The volume of Ghizela Mine is smaller than that of the other mine chambers in which measurements were made, and has a closed air circulation delimitated by doors. Consequently, in this saline chamber, carbon dioxide is influenced by door opening. On the one hand, if the door is open and air circulations is a faster, CO_2 concentration increase very slowly due to human presence but on the other hand, if the door is open, CO_2 concentration increases rapidly.

Considering the determined values that were very high, CO_2 concentration was also measured with the IR fotoacoustic method (table 4). The results indicated lower concentrations but closer values, as a result of CO_2 concentration variations on short intervals. However, differences between the measuring techniques of the two methods can also be taken into account**.**

Table 4. CO_2 concentration determined by IR fotoacustic method (10.08.2010)

Location / Meas. unit	Ghizela Mine	Rudolf Mine	Terezia Mine
mg/m^3	15883	17283	17683

Similar CO_2 concentrations were obtained in 2010 by the National Institute of Rehabilitation, Physical Medicine and Balneoclimatology. Hereby, a concentration of 14760 mg/m^3 were determined at 1.5 m height in Ghizela Mine, 12960 mg/m^3 in Rudolf Mine and 12240 mg/m^3 in Terezia Mine (Hoteteu, M., unpublished).

Besides the parameters mentioned above, the study included measurements of other compounds like: sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and methane (CH_4).

In 2010, our study revealed low concentrations of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) in Turda Salt Mine indoor air. In Rudolf Mine measurements indicated methane concentration up to 45.92 mg/m^3 and lower values up to 32.8 mg/m^3 for the other locations in which measurements were made.

PAHs were analyzed in Turda Salt Mine air, in Rudolf Mine and in Terezia Mine, because they could have been emitted during the rehabilitation works and also because the data were absent before.

The measurements indicate low concentrations of PAHs (table 5).

Table 5. PAH concentration in Turda Salt Mine (16.12.2009)

PAH type	*Ghizela Mine* (ng/m^3)	*Rudolf Mine* (ng/m^3)
Naphthalene	8.5	8.4
Acenaphtene	5.4	6
Benz(a)anthracene	6.2	4.3
Chrysene	0.0	2.7
Benzo(b)fluoranthene	2.2	7.6
Benzo(k)fluoranthene	4.5	1.4
Benzo(a)pyrene	5.6	1.1
Benzo(g,h,y)perylene	nd	nd
Indeno(1,2,3)pyrene	4.2	4.7
Total	36.6	36.2

Similar results have been obtained this year, by the National Institute of Rehabilitation, Physical Medicine and Balneoclimatology, concluding that hydrocarbons (HC) are present in indoor Turda Salt Mine air only in very low concentrations (Hoteteu, M., unpublished [3]).

Heavy metals measurements have been performed in two periods of the year: before Turda Salt Mine has opened to public and after six month from the opening. At the second measurement, in Rudolf Mine, the registered heavy metal concentration was even higher, especially for Fe, Cr and Ni (table 6).

Heavy metals could have been emitted, as fumes, during welding processes involved in the rehabilitation work of Turda salt Mine. These particles have been adsorbed onto salt particulate matter and since than, they have been carried around in the indoor air of the salt mine due to the absence of a proper ventilation system.

Table 6. Heavy metal concentration in Turda Salt Mine

Location / Heavy metal	Fe $\mu g/m^3$	Cr $\mu g/m^3$	Cd $\mu g/m^3$	Cu $\mu g/m^3$	Zn $\mu g/m^3$	Ni $\mu g/m^3$
Rudolf Mine Dec. 16th	0.13	0.014	0.07	0.33	0.066	0.017
Ghizela Mine June 15th	0.96	0.96	0.61	0.41	1.20	0.89
Rudolf Mine June 15th	2.23	2.62	0.62	0.51	0.09	1.64

The concentrations of volatile organic compounds, of formaldehyde and carbon monoxide are synthesized in table 7.

Table 7. Concentrations of VOC, formaldehyde and CO in Turda salt Mine (10.08.2010)

Location / parameters	Concentration (mg/m^3)		
	Ghizela Mine	Rudolf Mine	Terezia Mine
VOC	< 0.003	< 0.003	< 0.003
Formaldehyde	0.399	0.306	0.278
CO	2.71	2.39	2.65

The determined volatile organic compounds consisted in a series of compound classes like alcohols, halogenated compounds, monocyclic aromatic hydrocarbons and ketons. Formaldehyde was analyzed separately because it needed another analyzing technique. The measurements indicate a low concentration for VOC. However, formaldehyde was analyzed independently. High concentrations of formaldehyde are the result of the presence of parquet floor in Ghizela Mine, improper ventilation and presence of wood furniture in Rudolf and Terezia Mines. United States OSHA (Occupational Safety and Health Administration) recommends a Permissible Exposure Limit of 0.92 mg/m^3 and NIOSH (National Institute for Occupational Safety and Health) recommends 0.027 mg/m^3 for an 8 hour exposure. The Immediately Dangerous for Life and Health limit for formaldehyde exposure is considered to be a value of 24.5 mg/m^3. Moreover, IDPH (Illinois Department of Public Health) recommends a level of formaldehyde lower than 0.12 mg/m^3 for offices and 0.03 mg/m^3 for homes. Considering that Californian Standards recommend a limit of 10.3 mg/m^3 for 8 hours exposure in indoor air, and 22.9 mg/m^3 for 1 hour exposure, carbon monoxide concentrations determined in the Salt mine are very low and were not influenced in any way by rehabilitation works.

4. Conclusions

In conclusion, there are aspects of the rehabilitation works that influenced Turda Salt Mine's microclimatic parameters such as temperature, humidity, particulate matter concentration and presence of chemical compounds in indoor air composition. Furthermore, an increasing number of visitors lead to significant carbon dioxide concentrations, with consequence upon other microclimatic parameters.

However, the microclimatic parameters can be recovered trough a proper management plan that includes adequate ventilation in all mine chambers and certain restrictions regarding the number of visitors (Brisan N. et al, unpublished).

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