RGNZ/MGPB

Rudarsko-geološko-naftni zbornik
(The Mining-Geology-Petroleum Engineering Bulletin)
UDC: 622.4
DOI: 10.17794/rgn.2022.4.7

Professional paper

Comparability of microclimate in the horizons of the Trepça Mine in Stantërg

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Abstract
Analysis, assessment and comparison of climatic conditions of the stopes in the upper and lower horizons of the Trepça Mine in Stantërg, is as a basic principle to control as well as to improve them by providing a sufficient amount of fresh air to the main workplaces of the mine. The issue of the microclimate in various underground mining stopes shall require continuous measurements in the main places - stations, so for the overlying floors the previous measurements of the ventilation service were used for some stopes of deep horizons, and the measurements for certain time periods for 2021 have been forwarded. Measurements performed in different stopes of different horizons, creation of a database according to the obtained values and diagrams obtained for two microclimatic parameters (temperature and air humidity) as well as their analysis in scientific aspect offer us the best possible assessment which is argued in this paper. The presented results show that to improve the climatic conditions in the Trepça Mine in Stantërg, it is not only enough to change the ventilation system but also to direct (direction or regulation) a sufficient amount of fresh air in the direction of the analyzed stopes and those planned. This is done in order to provide better air conditions and to create a safe environment for the health of workers in underground work environments as a primary goal to increase high productivity of production.

Key words:
microclimate; amount of air; air temperature; humidity; air losses

1. Introduction

The Trepça Mine in Stantërg lies 10 km northeast of Mitrovica. This mine works as a special department within the mining-metallurgical-chemical plant "Trepça" in Mitrovica. The mine is connected to the Iber Highway near the city of Mitrovica, while the concentrate enrichment plant is located in the First Tunnel. On the left side of the river Iber, in Zvecan, is the smelter (**Zeqiri, 2004**).

Initially, the mine was opened through the gallery from the First Tunnel and then through the central well to the depth of horizon XI (from 760m to 12m AMSL), where 11 horizons with vertical distances of 60m were developed.

Creating suitable working conditions is the main object of focus in each working organization. This is done to create opportunities and mechanisms as appropriate as possible for the performance of mining work to have greater effectiveness and increase the quality of work, and at the same time aims to increase mining productivity by providing optimal working conditions. This is achieved by having the right amount of air in each workstation location and good removal of pollutants (harmful gases) (**Zeqiri, et al., 2011; Zeqiri, et al., 2011; Zeqiri, 2012**).

By analyzing the microclimatic conditions, initially, the fresh air must be regulated through the airways according to mine ventilation design. Many mining scientists have dealt with the regulation of air parameters in the Trepça Mine in Stantërg, always trying to connect many other parent mines with this mine. These goals, to connect these mines with the Trepça Mine in Stantërg, still remain unrealized, the connection of which would have importance and effect not only in connection with an increase of production, but would also greatly facilitate ventilation of the mine including the first horizon, level 610m (**Zeqiri, 2021**).

The main fan ventilator, old and new, installed in the Trepça Mine in Stantërg, have been considered as an opportunity for this mine and other parent mines to be analyzed separately from each other, also, have been considered as a joint study opportunity.

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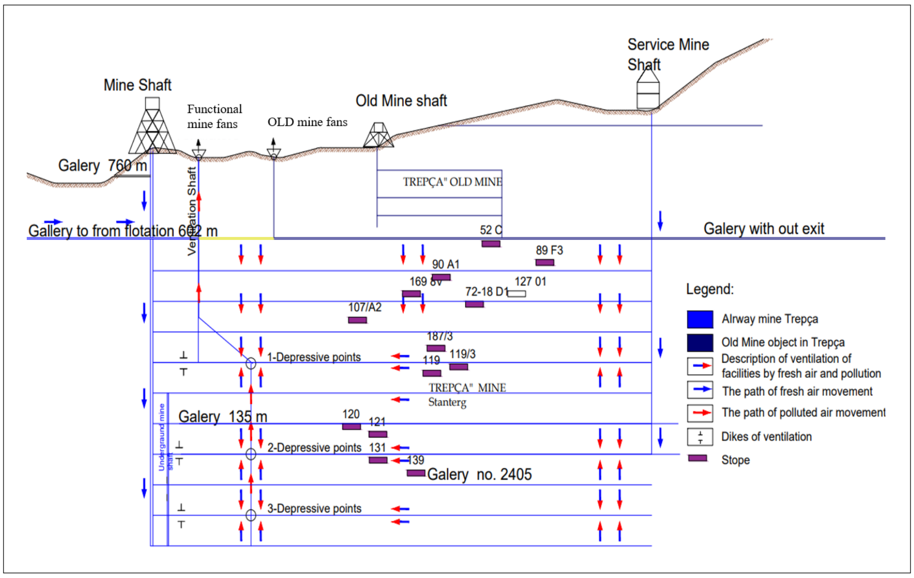

Figure 1: Ventilation scheme for the Trepça Mine (**Zeqiri, 2004**)

The Trepça Mine in Stantërg is surrounded by other parent springs such as: Mazhiq Spring (Quota 830m), Maja e Madhe and Xhidoma (**Zeqiri, et al., 2016; Zeqiri, et al., 2019**).

The microclimate parameters in this mine represent a set of environmental conditions, which, through the design and creative implementation of the central and local ventilation system, must be regulated and maintained in accordance with the norms of exploitation.

In this context, the ventilation system of the Trepça Mine in Stantërg, conceived and applied depending on the technical solutions of the underground mining technology, is quite complex and presents in itself many important problems to be solved and controlled, as it substantially influences the change of climatic working conditions on the exploitation fronts (see **Figure 1**).

The constant change of the physical parameters of the air, on the surface and underground, are closely related at the same time, both to the climatic conditions on the surface and to the technical and geothermal ones of the underground air movement, therefore the appropriate technical choice is a special importance in terms of economy, rationalization and provision of proper working conditions in the underground (**Abrashi, 1985; Goskolli, 2006; Goskolli, 2007**).

2. Microclimate in the upper mining horizons

The air condition of the mine and its impact on the workers are extremely important in carrying out any work. Air condition is defined by climatic factors, especially temperature and humidity. Its mission includes the supply of fresh air for underground staff, diluting and discharging harmful gases and floating dust and regulating the climatic conditions of the mine in order to create a good production environment (**Jinzhang, Peng, & Zhuang, 2020**).

In order to obtain an accurate idea of the physical parameters of the air entering the mine, measurements were made in real conditions with acceptable accuracy of the physical parameters of the air near the new ventilation shaft and the northern service shaft (**Kearney, et al., 2014**).

The results of measurements of climatic parameters, at the surface points of the mine during a calendar year, for both the old and the new ventilation system are given in **Table 1**.

In order to present the performance of the microclimate during a calendar year as clearly as possible, in some characteristic points of the mine, we have analysed the values of temperatures measured with a psychrometer in the dry (t_t) and wet (t_l) thermometer and the values of relative humidity j(%), in elevations 760m (mine surface) and 135m (deepest mine level) for the new and old ventilation system in different periods from 1972 to 2021 (see **Table 1**).

From the results of long-term measurements summarized in **Table 1**, for 1972 and 2021, we have the corresponding diagrams for air temperature and humidity (see **Figures 2, 3, 4, 5, 6** and **7**).

From the above diagrams (see **Figures 2, 3, 4, 5, 6** and **7**) visible differences are seen for the two parameters analysed, so we draw general conclusions regarding the comparisons made for both atmospheric air, and ground air (according to two ventilation system 1972 and 2021) as follows:

1. The air temperature in the underground workings throughout the year is higher than the atmospheric air temperature (**Figure 2, 3** and **4**).
2. The relative humidity of the air at the point of the underground workings is significantly lower than the humidity at the surface point of the mine (**Figure 5** and **6**).

Table 1: Monthly climatic parameters for the ventilation system, year 1972 and 2021 (**Zeqiri, 2004**)

Ventilation system														
The old ventilation system1972							New ventilation system 2021							
Zone							Zone							
Stope	Gallery 760m		Gallery 602m		Gallery 135m		Gallery 760m		Gallery 602m		Gallery 135m		Gallery 600m	
Depth	0m		158m		628m		0m		158m		135m		160m	
	Parameters													
Month	t_t [^{0}C]	φ[%]	t_t [^{0}C]	φ[%]	t_t [^{0}C]	φ[%]	t_t [^{0}C]	φ[%]	t_t [^{0}C]	φ[%]	t_t [^{0}C]	φ[%]	t_t [^{0}C]	φ[%]
I	2	84	5	76	17.8	78	1	69	9	66	15.8	67	7	74
II	5	86	8	87	24.6	96	1.5	75	12	69	16.8	69.5	7.7	71
III	9	64	22.4	73	19	66	2	57	11.5	68	17	65	8.9	75
IV	11	88	22.4	79	20.6	70	7	72	14	77	19	74	12	79
V	17	81	23	84	22.4	76	18	68	18	66	20	63	17.5	68
VI	21	75	24	84	25	70	18	71	18.2	71	20.1	64	16	68.7
VII	20	91	24	92	26.8	82	14	85	21	83	20.9	68	18.4	81
VIII	21	86	23.6	82	24.4	70	18	82	22	78	22	69	17.8	84
IX	14	85	23	82	24	84	14	82	23	84	22.5	79.4	14	77
X	12	89	22.4	87	20	74	7	65	17	65	18	66	12	68.4
XI	14	90	22.6	79	21	83	8.9	78	16	68	20	58.9	11.6	80.1
XII	2	97	20.2	76	15.6	66	5	76	18	67.5	21	75.8	8	77.2

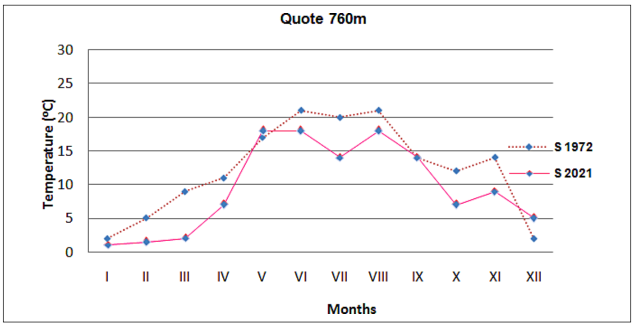

Figure 2: Monthly temperatures in the elevation 760m AMSL at depth H = 0 m

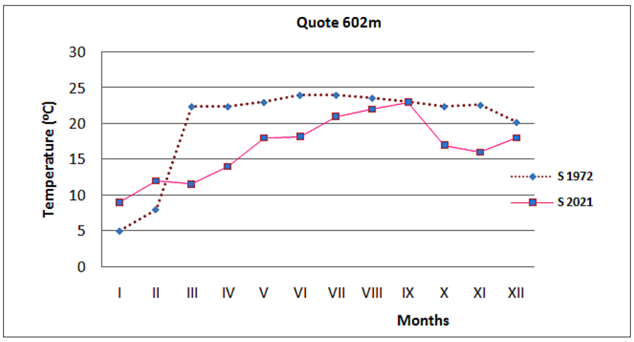

Figure 3: Monthly temperatures in the elevation 602m AMSL at depth H = 158m

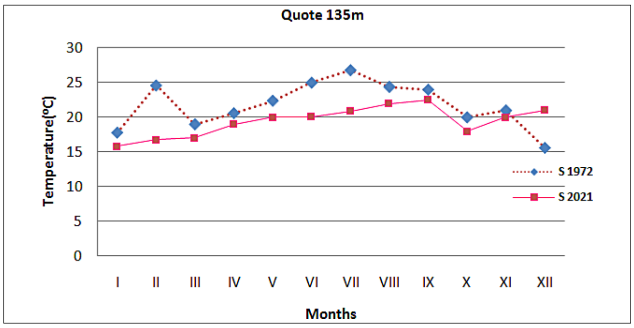

Figure 4: Monthly temperatures at elevation 135m AMSL at depth H = 628m

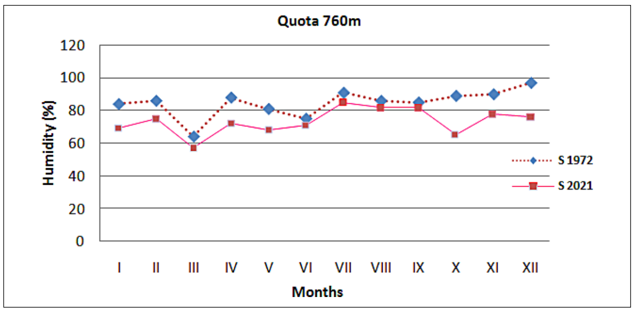

Figure 5: Monthly humidity in the elevation 760m AMSL at depth H = 0 m

Since the ventilation network of the Trepça Mine is quite complicated, a more emphasized analysis and comparability of microclimate have been executed in some underground stops, depending on the depth of the mine. The results of measurements for 1972, 1994 and 2021 are systematized in **Table 2**.

From the results of measurements for underground stope presented in **Table 2**, (air temperature and humidity) for

Table 2: Climatic parameters according to the depth of the stope for the ventilation system, year 1972, 1974 and 2021 (**Abrashi, 1985; Zeqiri, 2004**)

		Ventilation system					
		The old ventilation system, year 1972		The new ventilation system, year 1994		The new ventilation system, year 2021	
Parameters	**Depth**	**Dry tem**	**Humidity**	**Dry tem**	**Humidity**	**Dry tem**	**Humidity**
Stope	H[m]	t_t[^{0}C]	φ[%]	t_t[^{0}C]	φ[%]	t_t[^{0}C]	φ[%]
52/C –II	180	24.2	92	22.4	90	18	66.4
7218-III	230	25	95	21.8	92	18.4	82
12701-III	275	23	96	23	90	21	78.1
87/D1-IV	300	25	95	22	93	22	72
89/F$_3$-IV	300	24	96	23	97	22.1	72.3
90A$_1$-V	355	27.2	94	26.2	92	21.9	74.1
1698-V	385	23	92	23	92	21.7	68
107/A$_2$-VI	415	26.8	94	25.4	94	22.1	80
1873-VI	445	25	95	24	93	22	81
119/3-VII	460	26.8	94	27	97	22.8	79
119/B-VII	488	26.8	94	20	97	22.7	85
120/A-VIII	560	24	92	24.4	92	23	83.4
121-VIII	560	25	92	25	89	23.6	81.9
131-IX	625	27.6	95	26	93	22.2	87.6
139-IX	625	26.6	95	25.8	95	24.2	86.9
2405-IX	625			25	94		

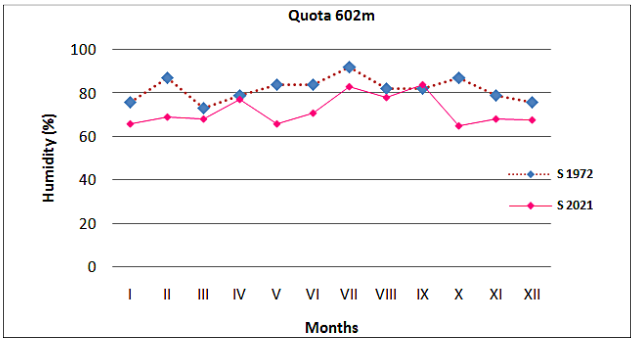

Figure 6: Monthly humidity in the elevation 602m AMSL at depth H = 158m

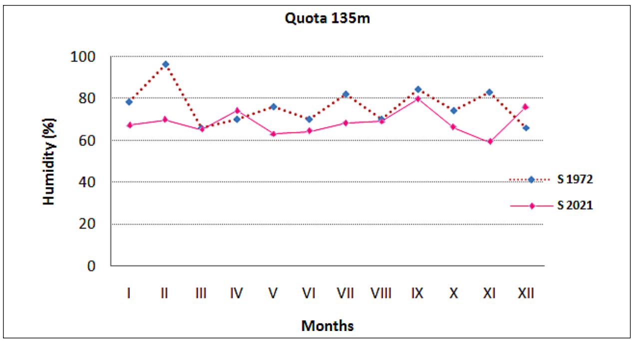

Figure 7: Monthly humidity at elevation 135m AMSL at depth H = 628m

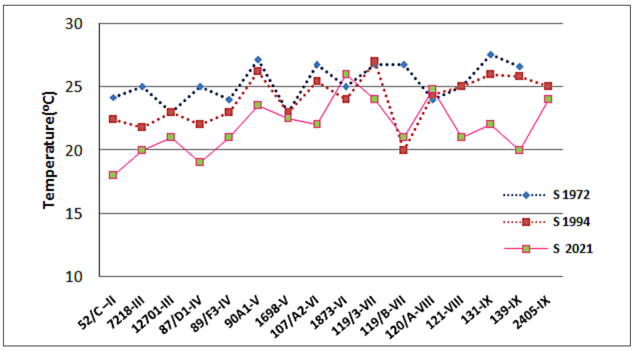

Figure 8: Workplace temperatures at different depths

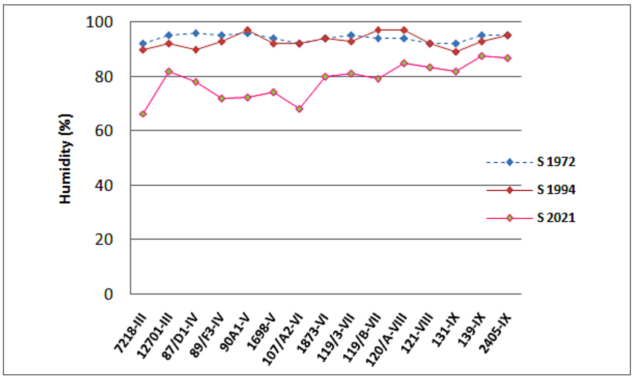

Figure 9: Relative humidity, according to the depth of the stope

the three-ventilation system, depending on their depth, **Figure 8** and **9** are constructed.

From **Figure 8** and **9**, it is noticed that:

1. The temperature of the working environment, regardless of its depth, is high, reaching the limit values allowed by literature used of the norms of Se-

curity Technique (**Nuredini, 1996; Development, 2016**).

2. The relative humidity, according to the depth of the stope, exceeds the values of 90-98%, both for the old ventilation system (1972 and 1994) and for the new ventilation system (2021) which varies in the range from 66.4% to 87.6%. However, although in the new ventilation system of 2021, the relative humidity is significantly lower than in the other two ventilation systems, it still presents a difficult and unsuitable atmosphere of the working environment.

In this regard, we conclude that the increase in the amount of air in the entrance spaces has very little effect on the improvement of climatic factors in the work environment, reducing the air temperature to invisible values, which is clearly seen from the comparisons made between the three ventilation systems.

3. Microclimatic conditions in the deep horizons of the mining

Based on the numerous research studies that are around the world in the field of mining technique and medicine, it has been concluded that man feels comfortable in the appropriate influence of the physical factors of the surrounding environment on the surface. Among these factors, we first consider air temperature, average surface temperature of radiation, air velocity, pressure, and humidity. Therefore, to analyse the microclimate of the deep horizons of the mine, the microclimate parameters were measured and studied in workstation 139, which is located at a level of about +135m, respectively at a maximum depth of 625m from the surface (see **Table 3**). To study the dependence of the change of microclimate parameters from the operating mode of the fan, periods of its operating mode from the maximum value of total pressure from about 4000 (Pa) to the minimum of 250 (Pa) are included in the measurement (**Zeqiri, 2004; Goskolli, 2018**).

In the operating mode of the main fan with total pressure 250 (Pa), air circulated only through the main corridors of the horizon, where the aerodynamic resistances were smaller, so the operating mode of the fan with minimal total pressure was caused by large air losses in the ventilation network, which have been the result of short circuits and insufficient stoppings in the main air outlets.

From the results of measurements of microclimate parameters in the working districts of the most characteristic stope: 52/C and 139, for both the old and the new ventilation system (see **Table 3**), we construct the respective **Figures 10, 11, 12** and **13,** for the temperature and humidity of the air.

From the analysis of the measured values and presented in **Table 3**, as well as in **Figures 10, 11, 12,** and **13**, we conclude that:

1. The air temperature in the highest-level environment (stope 52/c) is lower than the low temperature (stope 139). This conclusion is valid, not taking into account the change of ventilation system.

Table 3: Monthly climatic parameters for the ventilation system, year 1972, 1974 and 2021 (**Abrashi, 1985; Zeqiri, 2021; Zeqiri, 2004**)

Ventilation system												
	Old ventilation system 1972				New ventilation system 1994				New ventilation system 2021			
Stope	52/C		139		52/C		139		52/C		139	
Depth	180m		625m		180m		625m		180m		625m	
Parametrat / Month	t_t [°C]	φ[%]	t_t [°C]	φ[%]	t_t [°C]	φ[%]	t_t [°C]	φ[%]	t_t [°C]	φ[%]	t_t [°C]	φ[%]
I	24.2	92	26.6	95	22.4	90	25.8	95	21	81	24.2	80
II	24	92	26.6	95	22.8	90	25.6	9	21.8	79	23.1	81.2
III	24.6	92	25.6	95	24.6	88	25.6	92	21.6	72	23.6	78.9
IV	24.8	94	25.2	97	23.2	90	26	92	22	70.2	24	95
V	25.6	92	25.6	95	23	93	25.8	94	20.8	69.1	24.2	72
VI	25.6	92	27.4	97	23.4	92	26	92	21.9	82	24.3	78
VII	26.8	88	27	95	23.6	92	26	94	22	70.5	24.6	72.1
VIII	26	92	27	94	24	92	27	97	22.2	79.9	25	82.3
IX	25	97	26.8	94	24.4	89	26.2	95	22.9	85	25.6	82.2
X	24.8	95	27	95	23	92	26	92	21.9	84	23.9	83.3
XI	25	95	26.8	94	22	92	25.4	92	21.7	68	22.9	73.6
XII	25.4	94	26.6	95	22	92	25	92	20.4	74	23.7	75.7

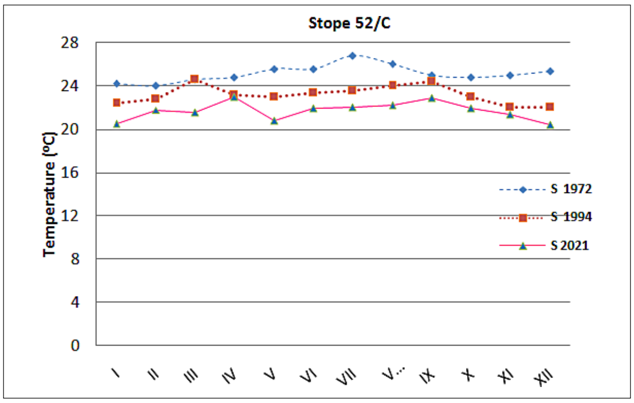

Figure 10: Monthly temperature in stope 52/c

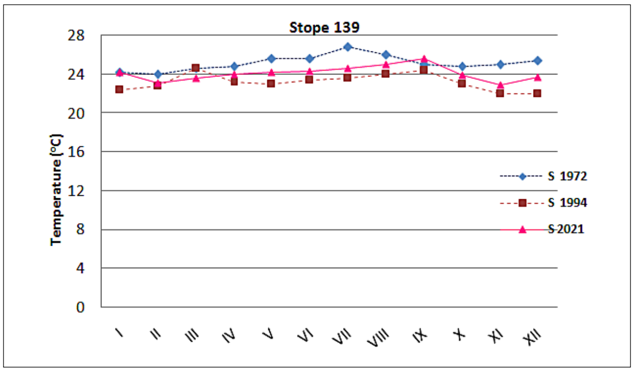

Figure 11: Monthly temperature in stope 139

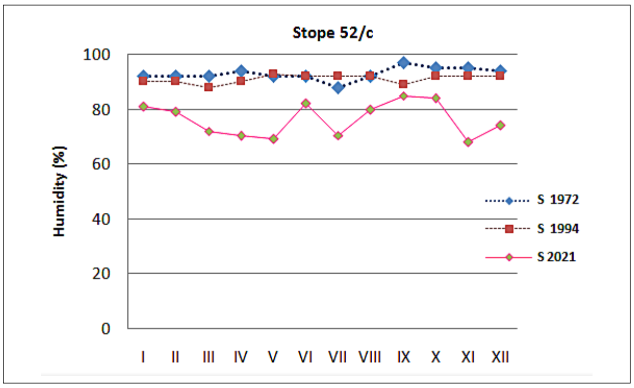

Figure 12: Monthly humidity in the stope 52/c

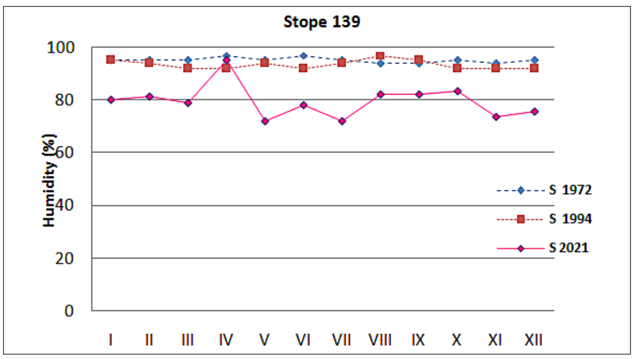

Figure 13: Monthly humidity in the stope 139

2. Relative air humidity (**stope** 52/c), regardless of the level of the stope, ventilation system and the annual season, has very large values above 92%, while in the 2021 ventilation system there is a significant decrease in variation 69.1% wide to 85%, which is characterized by extremely unfavourable conditions. At these high values of relative humidity in different stopes, the temperature difference between dry and wet thermometers does not exceed 1°C, which shows that the climatic conditions in these stopes are outside the limits provided by the legal norms of climatic conditions in the premises underground.

4. Conclusion

The state of the microclimate, regardless of the ventilation system, respectively the amount of fresh air in intake entrances, is almost identical for all stopes in the Trepça Mine in Stanterg. The unsuitable climatic situation of the working environment is characteristic of any period of the annual season. Based on this research, for the improvement of the climatic conditions in the stopes of the Trepça Mine in Stanterg, it is not enough just to change the ventilation system but the distribution of sufficient quantities of fresh air must also be applied in the direction of the analysed stope and the other planned stopes.

In this regard, it is also necessary to reconstruct ventilation routes that would provide sufficient amounts of fresh air flowing from the main corridors - galleries in the direction to these stopes. Also, the regulation and distribution of fresh air by ventilation doors, regulators, and special secondary fans will improve the climatic conditions on the mining stopes. As a precondition, it is necessary to reduce air losses in the ventilation network by applying insulation of old mined stopes and their hermetic seal and reconstructing existing ventilation galleries to increase the ability to move air with safe parameters.

The general conclusion derived from this research is that the aerodynamic resistance of the underground air routes in the galleries has large values created in the working environment. Therefore, instead of going through these galleries to the stopes, the air currents easily go to short connections of the minimum resistance, avoiding the work environment. Therefore, changes in air distribution in the ventilation network would also facilitate the work even with a greater number of workers engaged.

Acknowledgement

Most of the data is taken from the Trepça Mine in Stanterg, which we thank for the excellent, and correct cooperation. We also thank the Ventilation engineers of different companies who helped in the data collection.

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SAŽETAK

Usporedba mikroklime u horizontima rudnika „Trepča” u Stantërgu

Analiza i usporedba klimatskih uvjeta otkopa u gornjim i donjim horizontima rudnika „Trepča” u Stantërgu osnovni je princip kontrole i poboljšanja klimatskih uvjeta jer se na temelju tih podataka osiguravaju dovoljne količine svježega zraka na rudničkim radnim mjestima. Problem mikroklime u raznim podzemnim rudarskim radovima zahtijeva kontinuirana mjerenja na glavnim radilištima, stoga su za više horizonte korištena dosadašnja mjerenja ventilacijskih parametara, a za pojedina radilišta u dubljim horizontima korištena su novija mjerenja za vremensko razdoblje do 2021. godine. Mjerenja su obavljena na različitim postajama različitih horizonata, izrađena je baza podataka prema dobivenim vrijednostima te dijagrami za dva mikroklimatska parametra (temperatura i vlažnost zraka). Znanstvena analiza tih podataka omogućuje procjenu klimatskih parametara i mogućnosti njihova poboljšanja, predstavljenih u ovome radu. Prikazani rezultati pokazuju da za poboljšanje klimatskih uvjeta u rudniku „Trepča” u Stantërgu nije dovoljno samo promijeniti ventilacijski sustav, već je potrebno i pravilno rasporediti (regulirati) dovoljnu količinu svježega zraka prema otkopnim radilištima, onim postojećim i planiranim u budućnosti. To je potrebno radi povoljnijih uvjeta rada, ponajprije klimatskih parametara, čime se postiže i veća produktivnost rada.

Ključne riječi:
mikroklima, količina zraka, temperatura zraka, vlažnost, gubitci zraka

Author’s contribution

Izet Zeqiri (1) (Full Professor, Dr.sc.) data analysis, calculations and wrote the manuscript. **Frashër Brahimaj (2)** (Assistant teacher, Dr.sc. in blasting, Manager of blastings) Analyses of results, and presentation of results. **Rafet Zeqiri (3)** (Associate Professor, Dr.sc.) Realized measurements of air conditions in the Trepça Mine, performed the field work, and contributing with the data collect of ventilation. **Jahir Gashi (4)** (Dr.Sc. in mining engineering, Member of board of ICMM) contributed drawings, tables, and diagrams.