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Aim and Scope

Quality of Life publishes original research papers and reviews and aims to provide a forum for the rapid dissemination of significant novel research in the various disciplines encompassing the Science and technology of food, Public health engineering, Sanitary inspection and control, Environmental and public health. Topics covered by the journal include:

- Dietetics; Nutrition principles applied to foods
- Food Technology; Production and preservation of foodstuffs; Food preservation technique
- Industrial microbiology; Science and technique of applied microbiology; Applied mycology
- Public Health, environment and hygiene
- Hygiene of air, water, soil; Pollution and its control
- Water; Sanitation; Water treatment
- Sewage; Treatment, disposal, utilization of sewage
- Urban hygiene; Wastes; Refuse; Rubbish; Garbage; Collection and disposal of town wastes
- Measures against industrial and other nuisances
- Occupational health hazards; Occupational health and hygiene
- Ecology; Environmental engineering, sustainability and health
- Related topics

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Contents

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Dear readers,

it is my pleasure to present you the new issue of Quality of Life magazine and to thank you for your trust. In 2024, we continued to work to provide our readers with high-quality and interesting research papers in the various disciplines encompassing the Science and technology of food, Public health engineering, Sanitary inspection and control, Environmental and public health in our country, the region as well as at the international level. The topics covered in this issue of the Quality of Life magazine are diverse and address current issues in health, food technology, and environmental protection.

The journal Quality of Life was registered in the Register of Public Media in 2010 by the Decision of the RS Ministry of Education and Culture. Over the past years, this journal has published a large number of original scientific research papers, communications and review papers. Quality of Life is published twice a year by Pan-European University "Apeiron" Banja Luka. All the papers published so far have undergone a thorough review by the editorial board and the reviewers, made up of experts from both RS/B&H, the surrounding and other countries, from proven and recognized university and research institutions. As a result of a professional approach to selecting and reviewing papers, and raising the quality of the journal, Quality of Life was classified in the first category of journals in 2019 by the Ministry of Education and Culture. We are proud to say that Quality of Life has been well received by the scientific and the general public in a relatively short period, which gives the editorial board a strong motivation for further work. The editorial team would like to thank our many reviewers who helped to maintain the journal standard; our many authors who submitted their best work to the journal; and, most importantly, our readers for your continuing support. I assure all our readers that our consistent efforts will be aimed toward increasing the visibility, impact, editorial cycle time, citations and overall quality of our journal. We very much look forward to strengthening the reputation of our publications, and we want to attract more higher-quality submissions.

As always, I would like to thank the authors for their contributions to this issue of the magazine, and express great gratitude to all the reviewers who participated in the editorial process by providing valuable feedback to the editors and authors in a timely manner. We also extend our heartfelt thanks to the numerous authors who submitted their best papers to the magazine, and most importantly, to our readers for their continued support.

In the spirit of continuous improvement, any constructive input on streamlining our processes is very welcome. Please help us grow by citing articles that you read in Quality of Life. We look forward to receiving your contributions in the near future.

Editors

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Original scientific paper

Health Examinations of Persons Under Medical Supervision in Sarajevo Canton Before and During the Covid-19 Pandemic

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ABSTRACT: Introduction Data on the prevalence of streptococci, staphylococci, and salmonella in healthy people during the COVID-19 pandemic are lacking, and according to the results of studies related to patients with COVID-19, co-infections with the mentioned bacteria were rare. Since there is not enough data on the prevalence of germinalgia in healthy people at the time of the COVID-19 pandemic, that is The aim of this paper was to present the most frequently isolated causative agents in germ carriers in the period before and during the COVID-19 pandemic. **Material and method** A descriptive study was applied. The data source was the results of microbiological analyzes of nose and throat swabs, as well as examination of the stool of germ carriers, for the period 2018-2022. for Sarajevo Canton. The distribution of the most common isolates is shown. **Results** In the observed period, a total of 1,985 germ carriers were detected from all persons placed under medical supervision. In 2018 and 2019, a total of 73,838 were examined, and 790 (1.70%) carriers were detected. From 2020 to 2022, 79,276 were examined, and 1,195 (1.51%) were found to be germinal. Of the total number of isolates in germ carriers, the most represented was St. aureus, a total of 1935 (97.48%). In 2018 and 2019, it was isolated in 758 cases (39.48%), and from 2020 to 2022 in 1177 cases (60.82%). St.beta haemoliticus was isolated in 21 cases in 2018 and 2019, and in the same period Salmonella spp. code 11. From 2020-2022. St. beta haemoliticus was isolated in 14, and Salmonella spp. Code 4. **Conclusion** During the COVID-19 pandemic, there was an expected decrease in health examinations performed and a reduced number of detected carriers. During the COVID-19 pandemic, almost twice as many carriers of St. aureus, and the number of carriers of St. beta hemolyticus and Salmonellae spp. The number of germ carriers detected increased in the categories of pupils and students. The reason, the end of lockdown, socializing and inadequate wearing of masks, although according to the recommendations, those categories should also wear masks.

Keywords: health surveillance, germology, COVID-19 pandemic

INTRODUCTION

Germ carriers broadly refers to the symbiosis between a host organism and microorganisms, including bacteria, fungi, viruses, and other microorganisms. This community plays a key role in maintaining homeostasis, the immune system and in the digestive process of many living beings including humans. (1)

Through evolutionary processes, germplasm has adapted to various living conditions, developing specific interactions that often provide mutual benefits.

The germinability of pathogenic microorganisms represents an important challenge in understanding and controlling diseases in various organisms, including humans.

This dynamic interaction between pathogenic microorganisms and their hosts plays a key role in the development of infection and disease.

The germinability of pathogenic microorganisms refers to the specific interaction between pathogens, such as bacteria, viruses, fungi or parasites, and their hosts. This connection often results in serious health consequences for the host, as pathogens use different strategies to survive, reproduce, and cause disease. (2,3)

The variety of mechanisms by which pathogens cause disease include invasiveness, toxin production, the ability to evade the host's immune response, and other evolutionarily adapted strategies.

Understanding these mechanisms is crucial for the development of targeted therapies and preventive measures.

These pathogens have a significant impact on global public health, causing epidemics and pandemics, and posing challenges to medical systems and researchers. Timely recognition and suppression of germs is crucial for the prevention and control of infections.

Advances in molecular biology and other scientific disciplines enable the development of innovative approaches in the fight against pathogenic microorganisms. This includes the development of new antibiotics, vaccines and therapeutic strategies directed at specific targets.*(4)*

In the Law on the Protection of the Population from Infectious Diseases (Official Gazette of the FBiH, No. 29/05), special measures for the prevention and control of infectious diseases also include health surveillance of germ carriers, employees and other persons. *(5)*

Obligatory health check-up (sanitary check-up) is performed for certain categories of employees, other persons and germ carriers, which is carried out in order to prevent the occurrence of infectious diseases, under the conditions, within the deadlines and in the manner prescribed by the current legislation. *(6,7)*

Health examination of persons under medical supervision (sanitary examination) includes:

taking material and bacteriological examination of swabs of the throat and nose for germs (cooks, bakers, traders, restaurateurs, persons employed in preschool institutions, health workers, including pupils and students during education, persons working in the production, furnishing and dispensing of medicines, hairdressers , beauticians, persons who work in the production or sale of products for the hygienic needs of the population), collection of material and bacteriological examination of stool for germs and intestinal parasites (cooks, bakers, traders, restaurateurs, persons employed in preschool institutions, health workers employed in maternity and children's wards, hairdressers, beauticians, persons working in the production or sale of hygiene products population. *(6,7)*

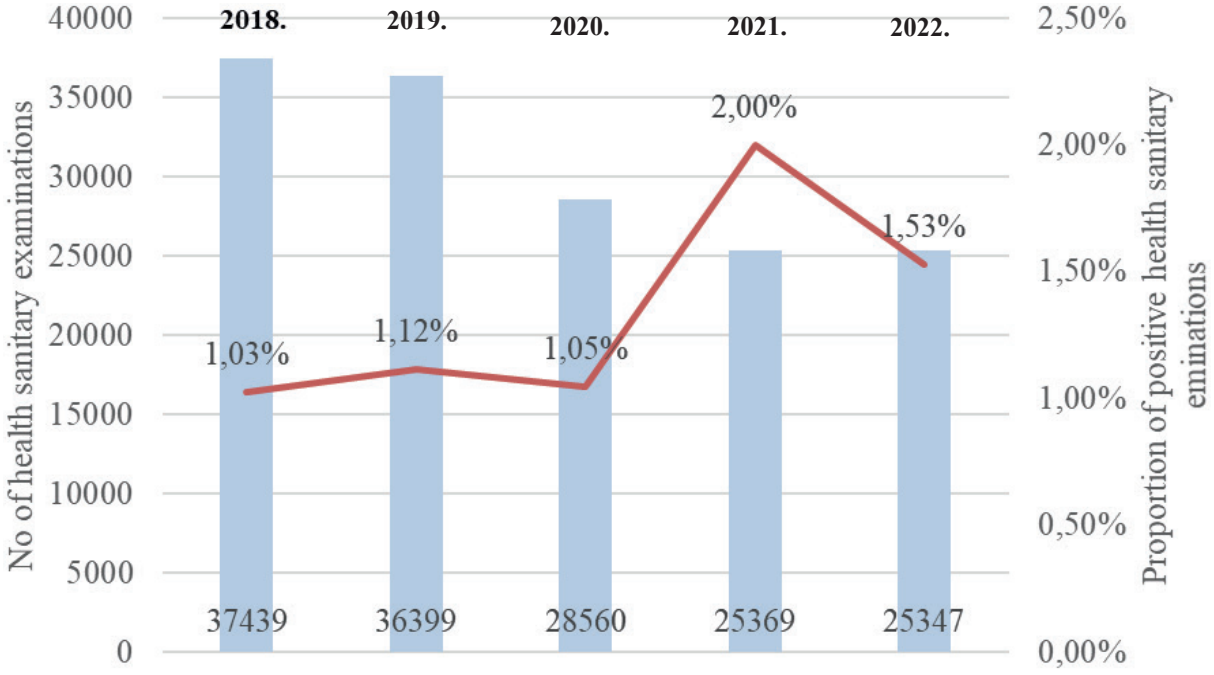
The aim of the work is to show the most frequently isolated causative agents in germ carriers in the period before and during the COVID-19 pandemic.

METHODS

A descriptive study was applied. The data source was the results of microbiological analyzes of nose and throat swabs, as well as examination of the stool of germ carriers, for the period 2018-2022. of the Microbiology Working Unit of the Institute for Public Health of Sarajevo Canton as well as the Germ Carrier Database of the Epidemiology Working Unit of the Institute for Public Health of Sarajevo Canton. Data processing was performed in the R studio program, and the results are presented graphically and tabularly. The distribution of data by age was tested with the Chi square test, with a significance level of $p<0.05$.

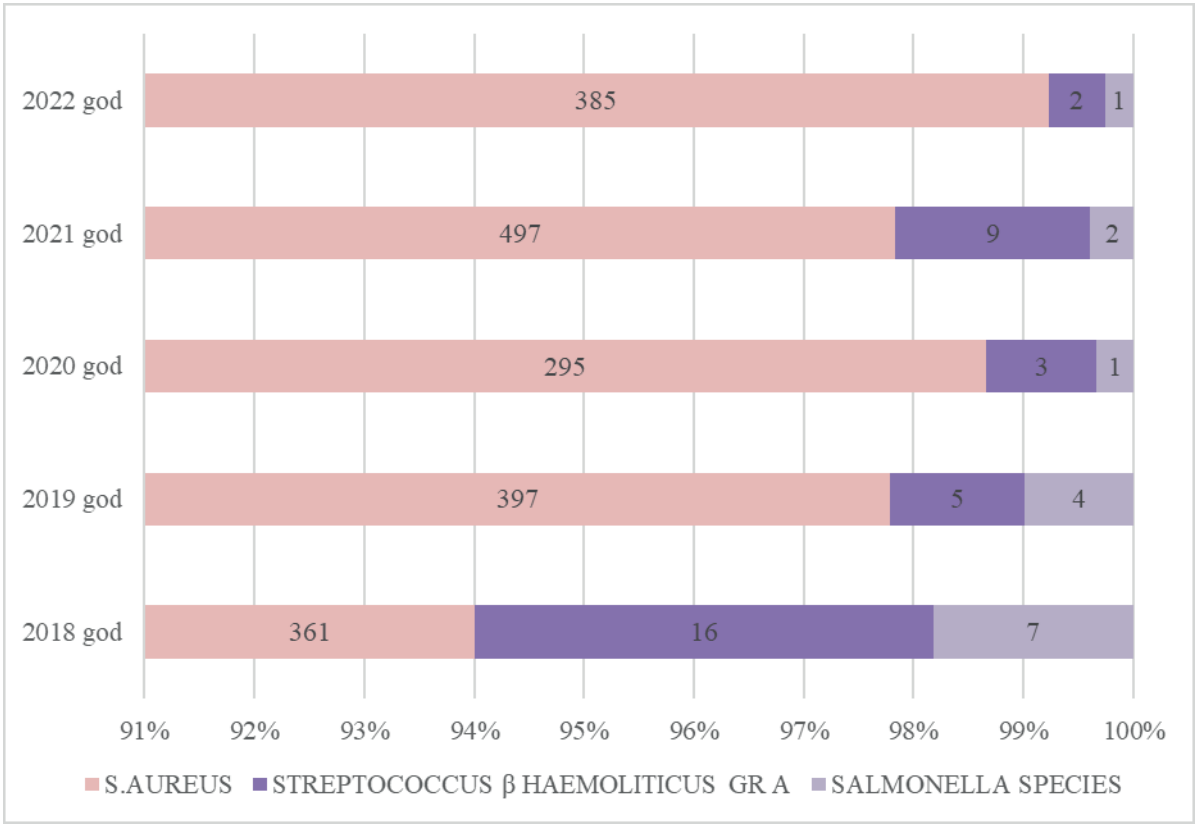
RESULTS

In the five-year period, a total of 153,114 samples collected during sanitary inspections were analyzed. In the mentioned period, the presence of pathogens was determined in 1,985 samples, that is, in 1.3% of the samples. The analysis of the samples in relation to the year and the proportion of positivity is presented in Graph 1.



Graph 1. Number of processed samples and the proportion of positive findings for the presence of pathogens

The analysis shows that during the period of the COVID infection, there was an increase in the proportion of positive analyzes for the presence of bacteria, pathogens, despite the decrease in the number of those tested. In 2021, that is, during the peak of the COVID-19 pandemic, 25,369 sanitary inspections were performed.



Graph 2. Proportion of pathogens found in positive samples

Table 1. Analysis of the presence of pathogens in relation to the subject's occupation

	Year	Caterers	Trade	Water supply	Schools and Faculties	Pre-school institutions	Health institutions - public	Health institutions - public	Pharmaceutical industry and public pharmacies	Private pharmacies	Production, traffic and care services
Staphylococcus aureus	2018	115 (31.86)	147 (40.72)	3 (0.83)	40 (11.08)	8 (2.22)	23 (6.37)	12 (3.32)	5 (1.39)	2 (0.55)	6 (1.66)
	2019	153 (38.54)	156 (39.29)	1 (0.25)	30 (7.56)	6 (1.51)	14 (3.53)	17 (4.28)	10 (2.52)	5 (1.26)	5 (1.26)
	2020	108 (36.61)	87 (29.49)	2 (0.68)	49 (16.61)	3 (1.02)	19 (6.44)	8 (2.71)	8 (2.71)	6 (2.03)	5 (1.69)
	2021	144 (28.97)	117 (23.54)	7 (1.41)	158 (31.79)	(0)	38 (7.65)	12 (2.41)	12 (2.41)	5 (1.01)	4 (0.8)
	2022	107 (27.79)	109 (28.31)	8 (2.08)	81 (21.04)	3 (0.78)	41 (10.65)	21 (5.45)	7 (1.82)	4 (1.04)	4 (1.04)
Streptococcus β haemoliticus grupa a	2018	4 (25)	8 (50)	(0)	2 (12.5)	(0)	(0)	(0)	(0)	1 (6.25)	1 (6.25)
	2019	1 (20)	2 (40)	(0)	(0)	(0)	(0)	1 (20)	(0)	(0)	1 (20)
	2020	2 (66.67)	(0)	(0)	(0)	1 (33.33)	(0)	(0)	(0)	(0)	(0)
	2021	(0)	1 (11.11)	(0)	6 (66.67)	(0)	(0)	1 (11.11)	1 (11.11)	(0)	(0)
	2022	1 (50)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	1 (50)
Salmonella species	2018	4 (57.14)	2 (28.57)	(0)	1 (14.29)	(0)	(0)	(0)	(0)	(0)	(0)
	2019	2 (50)	2 (50)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	2020	(0)	(0)	1 (100)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	2021	(0)	2 (100)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	2022	1 (100)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

Compared to 2018, when 37,439 inspections were performed, it can be seen that at the peak of the COVID-19 pandemic, 32.23% fewer sanitary inspections were performed. Despite this, it is observed that 2% of swabs were present for pathogens.

In the course of 2018, a total of 384 samples were tested for the presence of pathogenic bacteria, of which 94.01% of the samples were positive for the presence of S. Aureus, while 4.17% of the samples were positive for group B beta hemolytic streptococcus, and 1.82% on salmonella.

During 2019, 97.18% of positive samples were positive for the presence of S. Aureus, 1.23% for group B streptococcus, and 0.99% for the presence of Salmonella species.

During 2020, out of a total of 299 positive samples, 98.66% of them had positive samples, 1% Streptococcus, 0.33% Salmonella species.

During 2021, there were a total of 508 positive samples, of which 97.83% were due to the presence of S. Aureus, 1.77% due to the presence of beta hemolytic streptococcus and 0.39% due to the presence of Salmonella.

During 2022, a total of 388 samples were processed, of which 385 (99.23%) were positive for the presence of S. Aureus, 0.52% for the presence of beta hemolytic streptococcus and 0.26% for the presence of Salmonella.

DISCUSSION

The analysis determined that the largest share of positive findings on the presence of Staphyloccus Aureus is mostly found among restaurateurs and traders. In the course of 2021, it was observed that in the population of persons belonging to the category of schools and colleges, 158 of them had a positive smear for the presence of S.aureus, which represented 31.79% of all positive findings. In this category are pupils and students who carry out practical teaching related to their education, which includes going to catering facilities, shops or practical work in health institutions, kindergartens and children's collectives. The cause probably lies in the long-term lockdown during the COVID pandemic, which ended that year, which allowed the population of persons belonging to the category of schools and colleges to come into contact and classes took place in schools and colleges and apparently without protective measures. It was observed that in the same period there was no significant increase in positive findings in the category of health workers, which, although the increased number of examinations in health institutions was accompanied by protective measures by health workers. It can be seen that the COVID pandemic has also led to changes in the occurrence of S. aureus in the population. ($x2=172.24$, $p<0.001$).

Streptococcus beta hemolytic was found mostly among caterers, but during 2021 it was also observed that as many as 66.67% of isolates with the presence of this pathogen were in the group of persons belonging to the category of schools and colleges. Salmonella is detected individually, and in 2018 as many as 57.14% of positive samples were among caterers, and 28.57% among retailers. During the COVID pandemic, especially in 2021, two findings with the presence of salmonella were isolated, both in store workers, and in 2022, one isolate was found in caterers.

CONCLUSION

During the COVID-19 pandemic, there was an expected reduction in health examinations of persons under medical supervision and a reduced number of detected germ carriers. During the COVID-19 pandemic, almost twice as many carriers of St. aureus, and the number of carriers of St. beta hemolyticus and Salmonellae spp. St. aureus is one of the most common and common bacterial pathogens in humans, and in about 30% of people it is found in the nasal vestibule. S. aureus is ubiquitous among people, it

spreads from person to person by direct or indirect contact through various objects and droplets during sneezing and coughing. The number of carriers detected is increased in persons who belong to the category of schools and colleges that are placed under health surveillance and thus further spread of pathogens is prevented. Although there was a decrease in the number of health examinations during the COVID-19 pandemic, measures for the prevention and control of infectious diseases, which include health surveillance of germ carriers, employees and other persons, have shown their effectiveness.

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Original scientific paper

Environmental Assessment of Particulate Matter Pollution Generated by the Exploitation of Heliopolis Aggregates Quarry

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ABSTRACT: In recent decades, extractive industries such as mining and quarrying have contributed to increasing environmental deterioration, particularly airborne emissions. Therefore, we aim to evaluate the environmental impacts of particulate matter (PM1, PM2.5, and PM10) emitted during the exploitation operations of aggregates in the Heliopolis quarry in Guelma, Algeria. For this purpose, dust samples were analyzed using XRD and XRF spectroscopy techniques. While preparing the gravel, we monitored air quality using a specialized device and analyzed flora samples from near the Heliopolis aggregates quarry. Furthermore, we conducted chemical and physical analyses of surface water samples and soil from a nearby farm. The obtained results show that the concentrations of PM (particulate matter) exceeded the WHO limit values for PM10 (50 µg/m^3) and PM2.5 (25 µg/m^3) within 24 hours. This was particularly noticeable in sampling stations S1 and S2, where the PM2.5 concentration was at 520 µg/m^3 and PM10 at 684 µg/m^3, and 516 µg/m^3 and PM10 at 676 µg/m^3, respectively. According to the XRD and XRF analyses, the quarry dust contains various minerals, including oxides and heavy metals. An analysis of the plants surrounding the Heliopolis quarry confirms the presence of dust containing the same mineral elements emitted from the quarry on the leaves and branches of trees, which hinders their natural growth and blocks sunlight.

Keywords: airborne pollution, mining operations, plant stress, soil and water pollution, Guelma, Algeria

INTRODUCTION

The ongoing industrial development has heightened environmental issues, causing increased air, water, and soil pollution. The proportion of natural resources has recently declined due to overexploitation (Dong et al, 2014). A specific example of this trend is evident in the production of concrete, where it now takes two tons of gravel to yield one cubic meter of concrete (Danielsen & Kuznetsova, 2014), recognizing that gravel is not a sustainable resource, the focus shifts towards sustainability by repurposing the quarry for activities such as investment projects once its operations conclude. This may include community-serving recreational investments for locals, such as open swimming facilities, sports stadiums *etc...* (Najafi, Hamzeh, & Moqimi, 2014).

The quarry dust composition varies depending on the geological characteristics of the area where the quarry is located. For instance, aggregates quarry dust in Nigeria typically contains heavy metals such as Cu, Pb, and Zn (Ajibade, Olisa, Oladipupo, Adegoke, & Adebayo, 2022), in contrast, our investigation at the Heliopolis aggregates quarry revealed the presence of SiO_2, CaO, MgO, and Fe_2O_3. This difference is due to the specific geological characteristics of each studied quarry site. Therefore, the diversity of the properties of these particles leads to the diversity of infection. (''World Health Organization'', 2021).

The environmental situation in Heliopolis is deeply concerning, particularly in light of the findings, especially concerning atmospheric particles found in quarry dust with an average aerodynamic diameter

of less than or equal to 10 μm and 2.5 μm (PM10, PM2.5). Given that, the study area in Heliopolis experiences high temperatures during the summer frequently surpass 43 degrees Celsius as the map indicates in Figure 2, can even reach 45.5 degrees for the southern part of Heliopolis. Recent research has validated the significant role of temperature and humidity in intensifying pollution severity and dispersing these particles into the air, especially among workers (Materu, Sway, & Mussa, 2023).

These fine substances infiltrate deeply into the lungs and bronchi, enter the bloodstream, and exert effects on the vessels of the heart and brain. Recent evidence suggests that inhaling PM2.5 and PM10 also influences other human organs, contributing to the onset of various diseases (''WHO'', 2022).

About 7 million people succumb annually to the exacerbation of air pollution, with 90 % of these fatalities concentrated in low- and middle-income nations such as Algeria (Rentschler & Leonova, 2022), where, in 2022, PM2.5 concentrations were 3.6 times the World Health Organization's annual indicative value for air quality (''WHO'', 2022). Workers who spend more than eight hours in quarrying stations or other related quarry services face the risk of exposure to various dust particles containing significant elements like silicon dioxide (SiO_2) and calcium oxide (CaO), Aluminum (Al) which can cause several occupational diseases like silicosis (Liang, McCoy, Tomasallo, & Meiman, 2023). Hence, air pollution can result in an irregular heartbeat. Significant acute effects include an increased risk of coronary syndromes and high blood pressure (Argacha, 2023). Although legal emission standards are met in some cases, workers in this sector often suffer from symptoms such as headaches, eye allergies, and fatigue. This highlights the danger of exposure to these particles, even at low concentrations (Ferreira et al, 2023). Moreover, Primary emissions in mining arise from mechanical methods such as drilling and explosions, which release PM10, carbon dioxide, sulfur oxide, and various metals. Material transportation using diesel engines contributes significantly to the environmental impacts associated with quarrying activities (Boutemedjet, Bounouala, Idres, & Benselhoub, 2019; Bascompta, Sanmiquel, Gangolells, & Sidki, 2022).

Despite widespread attention, a practical system for early detection of air pollution remains lacking in new technologies (Li & Zhu, 2018). By employing our evaluation method, we can precisely gauge the environmental impacts of quarrying activities. This enables us to anticipate and tackle potential issues before they escalate, empowering us to make informed decisions to prevent further damage. Our goal is to raise awareness among people about the significance of acknowledging pollution stemming from particulate matter emissions and actively engaging in monitoring its dispersal (Yu & Zahidi, 2023).

Reducing air pollution yields numerous benefits, including enhanced health by mitigating respiratory diseases and reducing worker mortality rates. Additionally, it positively affects the economy, saves time, and plays a pivotal role in attaining environmental security and fostering sustainable development (Geng et al, 2019).

In this article, we will examine the environmental impacts of particulate matter emissions from quarries. These emissions include atmospheric pollution (dust), which can affect plant health, water quality, and soil accumulation. Our paper will discuss the most significant side effects of quarrying, with a specific focus on the environmental assessment of particulate matter produced by the mechanical preparation of gravel used in buildings and various urban constructions.

MATERIALS AND METHODS

Study Area

Our research has been conducted in Heliopolis, located approximately 5 km northeast of Guelma city in eastern Algeria, North Africa, as depicted in Figure 1a. This county is renowned for its substantial

economic contributions. The region of Guelma is characterized by a plethora of tourist attractions, archaeological sites, a thriving agricultural sector, stunning landscapes, and a rich cultural heritage.

The Heliopolis quarry is situated on a terrain with a diverse geological composition as noticed in Figure1b. The area comprises a variety of rocks dating back to different eras, such as the lower Cretaceous and Jurassic, upper Cretaceous, Santonian, Senonian, Cenozoic Oligocene, and Quaternary.

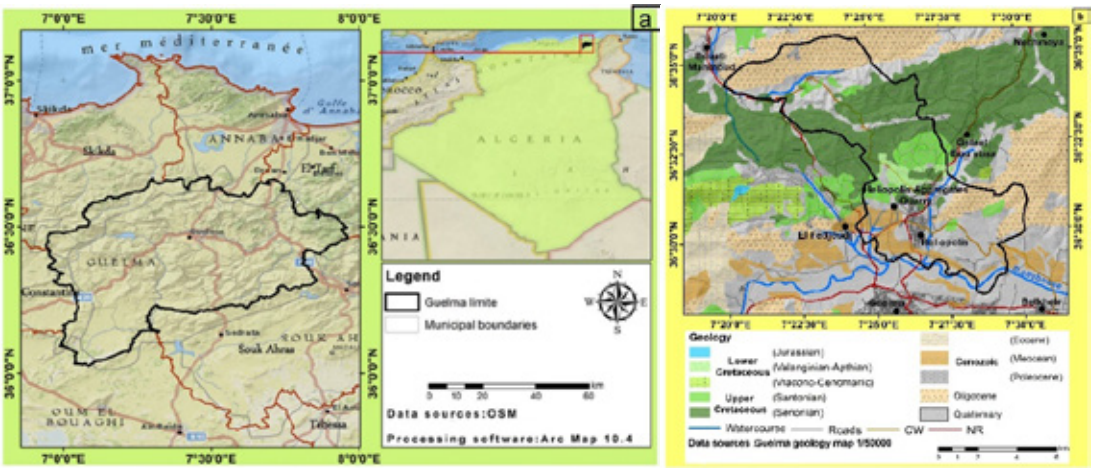

Figure 1. Study zone of Heliopolis, Guelma, Algeria: (a-geographical situation of the study area, b-geological map of Heliopolis)

Description of Aggregates Extraction Method

Figure 2 represents the aggregates exploitation method in open-pit mode (surface). The aggregates extraction methods primarily rely on the removal of vegetation cover (soil, trees and plants) to construct structures that facilitate access and exploitation.

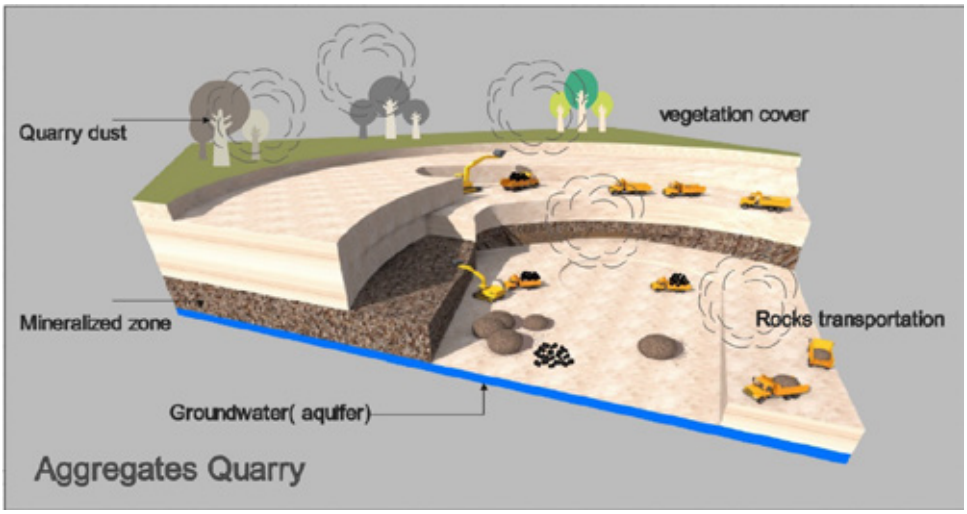

Figure 2. Aggregates exploitation methods

Quarrying depends on minimizing the aggregates stone size through drilling and blasting. Miners use explosives to smash and break rocks, after which they transport the stones to crushing stations. At Heliopolis Aggregates Quarry, they utilize two-wheel loaders and transport trucks. The quarry is equipped with three crushing stations (primary and secondary). The crushed rocks undergo initial screening, and in the second stage, the final gravel product becomes commercially available with varying grain sizes (0–3, 3–8, 8–15, and 15–20 mm).

Sample Collection Sites

We have installed six dust-monitoring stations (S1, S2, S3, S4, S5, and S6) at various distances between the inside and outside of the Heliopolis aggregates quarry from September 2021 to March 2022. These stations were set up to assess the air quality, as shown in Figure 3.

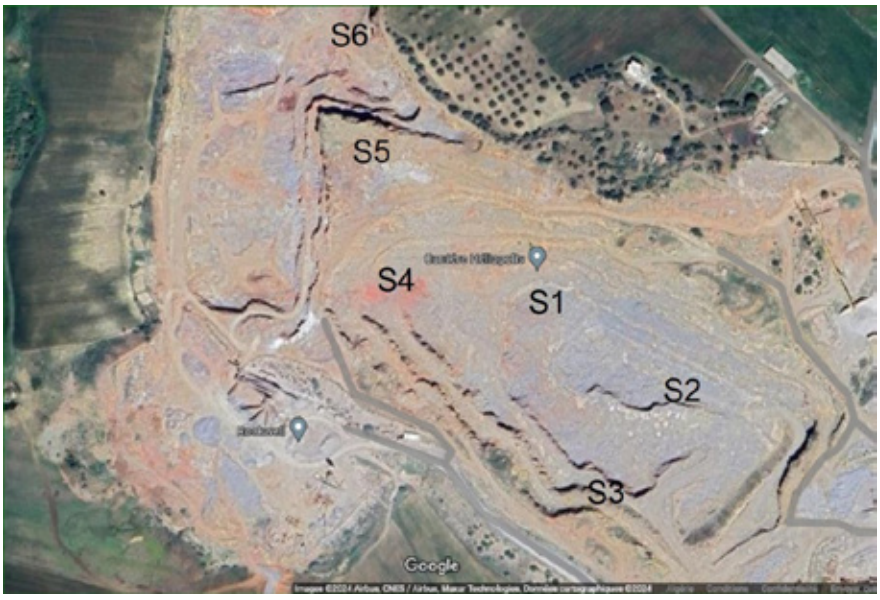

Figure 3. Dust sampling stations positions in Heliopolis quarry (‘’Google maps”, 2024)

Then, we used (XRF) X-ray fluorescence and (XRD) X-ray spectroscopy (Secchi et al, 2018) to analyze all of the dust samples collected from the quarry. In addition, we have applied an air quality monitor during the exploitation operations as seen in Figure 4a.

X-ray diffraction (XRD) analysis, an advanced analytical technique, offers numerous advantages for detecting mineral compositions within samples under study and processing, such as dust, rocks, and soil. This technology assists researchers in uncovering the environmental impacts of these formulations, allowing for precise analyses without distorting the sample or compromising its properties (‘’Analyse De Matériaux Par DRX (Diffraction Des Rayons X), 2023 ‘’). After preparing the sample—mineral dust gathered during exploitation activities—subsequently, we performed X-ray spectroscopy to ascertain the quantity and types of metal oxides present in the dust samples. This procedure was straightforward and automated (Zhou, Wang, Wang, & Liao, 2023) as noticed in Figure 4b, and Figure 4c.

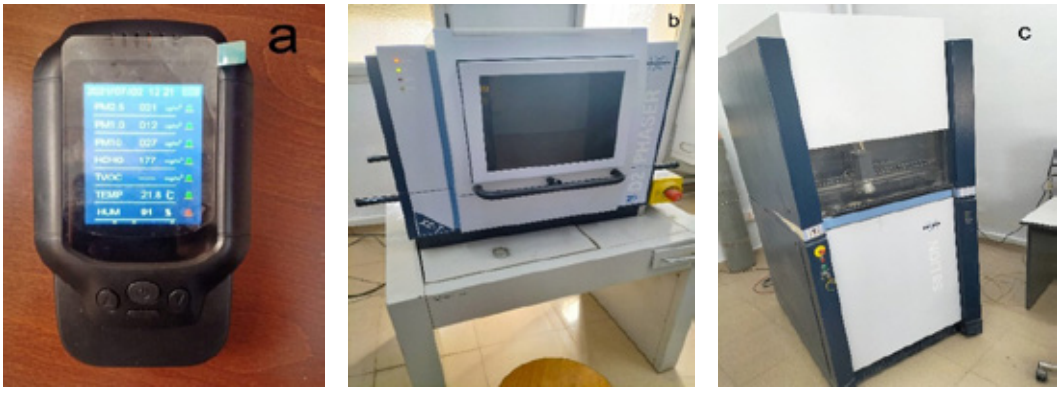

Figure 4. Equipment used in the quantitative and qualitative analysis of dust emitted from the quarry (a: The air quality meter: a multifunctional air quality-measuring device PCE-RCM 8. Brand: Fambasis, b: Benchtop X-ray diffractometer BRUKER D2 PHASER, and c: Fluorescence spectrometer S8 LION, dispersive X-ray machine Bruker AXS (manufactured in Germany)

Flora Pollution Assessment

We collected six samples to assess the impact of quarry dust on plants and trees. The samples included three plant species: laurel, mallows, and wild thistle, found near the Heliopolis quarry. We also brought branches from pine, olive trees, and eucalyptus from a nearby farm. We then conducted a physico-chemical analysis of the samples at the soil and water analysis laboratory in Annaba, Algeria. After being sun-dried, the plants were pulverized and subjected to a variety of chemical treatments, one for each type of mineral. To ascertain the concentration and amount of significant chemical species, such as SiO_2, $CaCO_3$, and Al_2O_3, that were present in the dust samples, this technique is known as the chemical dosing method.

Water Pollution Evaluation

We gathered water samples from the surface water located near the aggregates quarry in Heliopolis, Guelma. After collecting the samples, we conducted a thorough analysis of the water's physical and chemical properties. Our main goal was to determine whether the quarry dust contained any significant elements that could potentially affect the nearby water source. This would help us establish a connection between the quarrying activities and their potential impact on the surrounding watercourses.

Evaluation Of Soil Contamination

We brought soil samples from a farm near the Heliopolis aggregates quarry at a depth of 50 cm to assess soil accumulation. These samples were analyzed for their physicochemical properties at the "Soil and Water Analysis Laboratory" in Algeria. Additionally, we conducted XRD and XRF analyses to identify the important elements present in the soil. These elements can have a direct impact on plants and may cause groundwater pollution.

METEOROLOGICAL CONDITIONS

Temperature Variations

We observe that the Heliopolis area has a relatively hot climate, as indicated on the map in Figure 5.

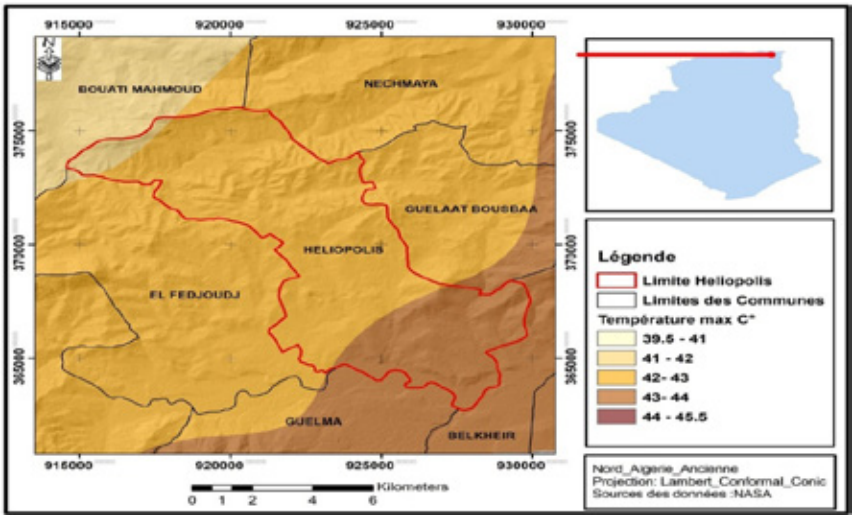

Figure 5. Temperature variations across the Heliopolis region

In the northwest, temperatures range from 39.5 to 41 degrees Celsius, while the central and eastern parts of Heliopolis experience temperatures between 41 and 43 degrees. In the southern region, temperatures soar to 45.5 degrees.

Wind Rose

The wind rose chart for the Guelma study area presented in Figure 6 illustrates the number of hours that the wind blows in a specific direction throughout the year.

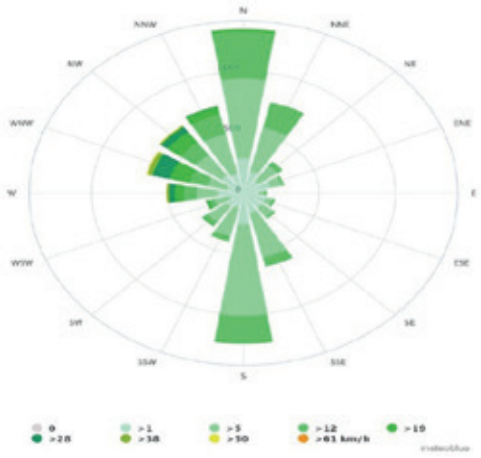

Figure 6. Wind rose chart of Guelma region (''Météo bleu'', 2024)

In this area, the prevailing wind direction is from the southwest (SW) towards the northeast (NE). As a result, station S6 experiences high levels of quartz and calcite, in addition to significant pollution of the flora in this side. This is attributed to the direct influence of the wind, which facilitates the spread of dust particles in the region.

RESULTS AND DISCUSSION

Pm Pollution Quantification

According to Figure 7, S1 and S2 are the most contaminated stations. The daily averages at S1 are PM2.5: 516 µg /m^3 and PM10: 676 µg/m^3, and at S2, PM2.5: 520 µg/m^3 and PM10: 684 µg/m^3, respectively.

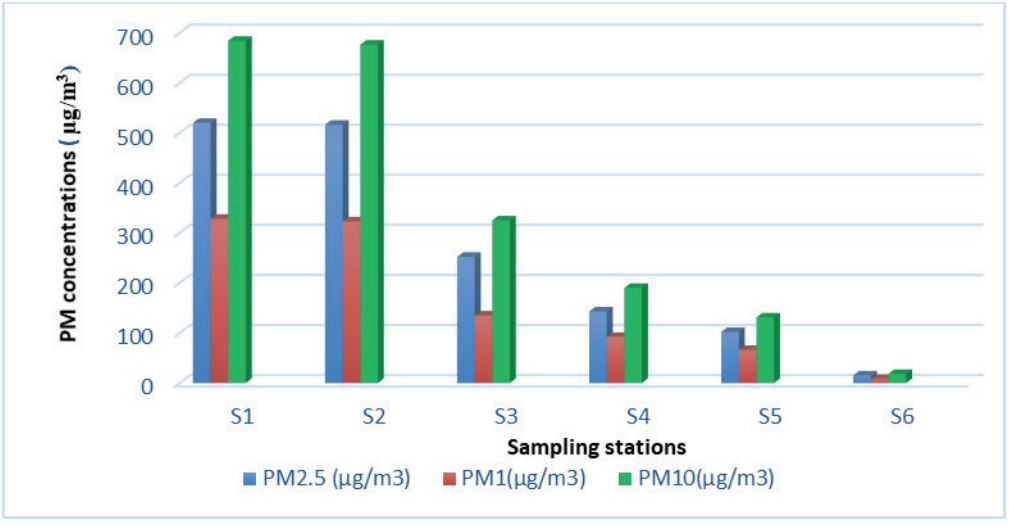

Figure 7. Dust concentrations in the Heliopolis aggregates quarry using an air quality monitor

These values exceed the WHO's maximum annual recommendations for PM2.5: 25 µg/m^3 and PM10: 50 µg/m^3 (''WHO'', 2024), as well as the Algerian limit concentration of 80 µg/m^3 (Kerbachi, Boumechhour, Arrar, & Boughedaoui, 2009).

Table 1. Minerals detected by X-ray diffraction (XRD) in Heliopolis aggregates quarry dust

Minerals (%)	S1	S2	S3	S4	S5	S6
Quartz	4.38*	1.34	2.26	1.3	2.63	8.25
Calcite	90.82	48.24	93.36	79.85	71.71	60.21
Dolomite	0.58	40	0.16	10.33	18.97	8.29
Siderite	0	0	0	0.21	0	0
Ankerite	0	9.03	0	0.53	2.53	2.53
Magnesite	0.62	0	1.33	2.37	0.44	2.86
Pyrite	0.28	0.10	0.10	0.20	0.06	0.32
Illite	0.49	0	1.07	0.87	2.27	9.77
Kaolinite	2	0.96	1.36	1.85	0.98	7.15
K-feldspaph	0.83	0.33	0.36	2.48	0.41	0.63
Total (%)	100	100	100	100	100	100

Note: *4.38% (4.38×104 ppm)

Among the major minerals identified, calcite ($CaCO_3$) exhibits the highest concentrations, with 93.36 % in S3, 90.82 % in S1, and 79.85 % in S4. Subsequently, there is a decrease in the percentage of calcite to 48.24 % at Station S2, although it remains notably high compared to other chemical elements. These findings were determined through XRD examination of all the dust stations listed in Table 1. Human exposure to calcite dust can irritate the eyes and respiratory system, causing asthma with continuous exposure (Lyu et al, 2022).

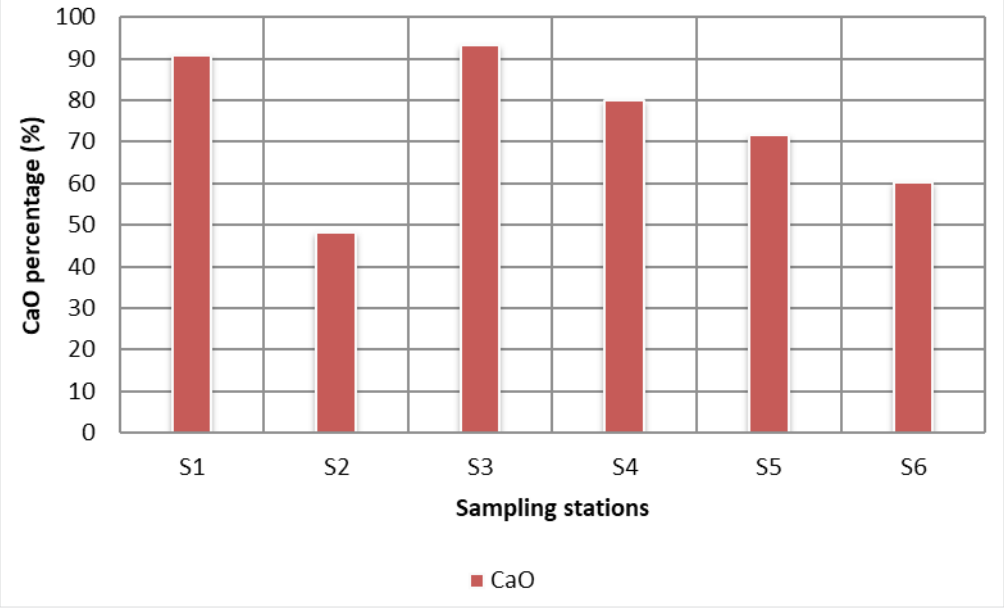

Figure 8. Differences in the amounts of CaO in quarry dust at sampling locations

The noticeable increase in the percentage of calcium oxide in Figure 8, especially at sampling stations S1 and S3, can be attributed to their proximity to primary crushing stations. Additionally, during the unloading of trucks, there is a significant increase in dust concentrations, specifically by 30 times. This increase is primarily due to the dispersion of airborne particles smaller than 2.5 µm in size, in contrast to periods when unloading is not taking place (Liu et al, 2023). It is worth noting that the prevalence of limestone characterizes the geological composition of the study area (Bouaicha, Dib, Belkhiri, Manchar, & Chabour, 2017), that is why nearly all sample stations have a high percentage of calcite dust.

Concerning the presence of the dolomite mineral CaMg $(CO_3)_2$, it is remarkable, reaching a substantial concentration of 40 % in S2. The main constituents of dolomite are magnesium carbonate, calcium carbonate, and limestone. It might also include heavy metals like lead (Semmeq et al, 2021), human respiratory health may be in danger from prolonged exposure to dolomite, and these include coughing, phlegm production that is elevated and breathing difficulty. A decrease in lung function may result from extended exposure, particularly at doses higher than 10 mg/m^3 (Neghab, Abedini, Soltanzadeh, Kashkooli, & Ghayoomi, 2012).

The XRF analysis depicted in Table 2 reveals important CaO concentrations at 55.78 %, 53.63 %, 48.94 %, 48.7 %, 47.1 %, and 30.38 % across all sampling stations (S1, S2, S3, S4, S5, and S6), its levels gradually decline with increasing distance from the emission source.

Table 2. XRF analysis results of dust samples

Station Content %	S1	S2	S3	S4	S5	S6
SiO_2	3.86*	1.25	1.38	0.26	3.45	18.20
Al_2O_3	0.42	0.13	0.27	-	1.54	8.77
Fe_2O_3	0.53	0.18	1.42	0.27	0.67	3.26
CaO	55.63	48.70	53.78	48.94	47.1	30.38
MgO	0.64	7.6	0.44	2.28	3.79	2.09
SO_3	0.18	0.01	0.04	-	0.15	0.99
K_2O	0.11	0.04	0.05	0.01	0.15	0.44
Na_2O	0.08	0.09	0.08	0.09	0.09	0.14

Note: *3.86 % (3.86×10^4ppm)

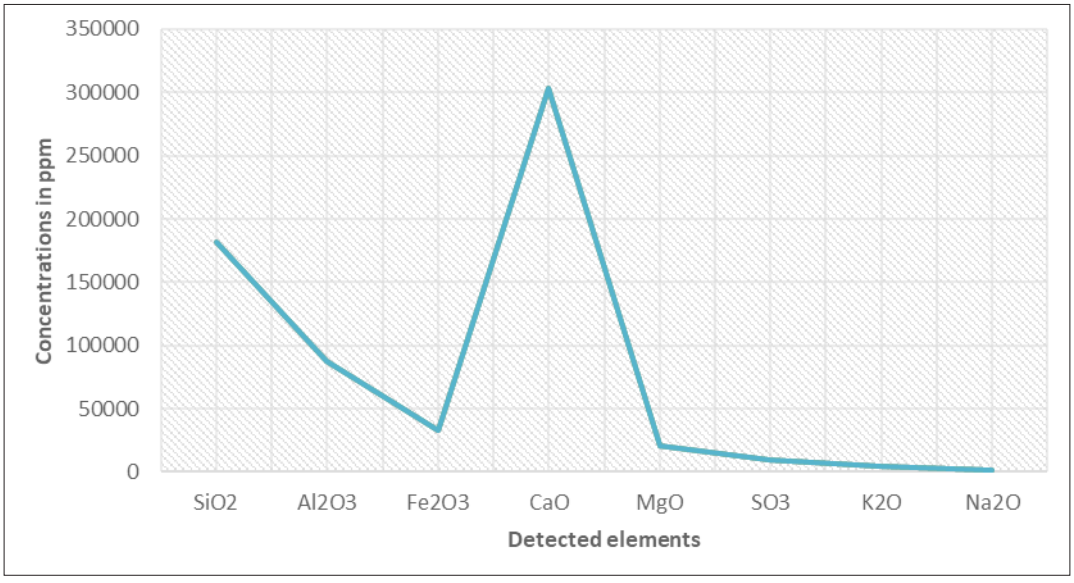

Figure 9. XRF analysis of the quarry dust sample collected at station S6

Despite the generally low presence of silicon dioxide (SiO_2) in all dust-sampling stations, station S6 stands out with an observed concentration of 18.20% (18.2×10^4 ppm) as noticed in Figure 9.

Although not to the same extent as silicon dioxide, aluminum oxide Al_2O_3 concentrations are detectable in the dust samples and diminish gradually. Additionally, several other minerals are present in low concentrations, including Fe_2O_3, MgO, SO_3, K_2O, and Na_2O.

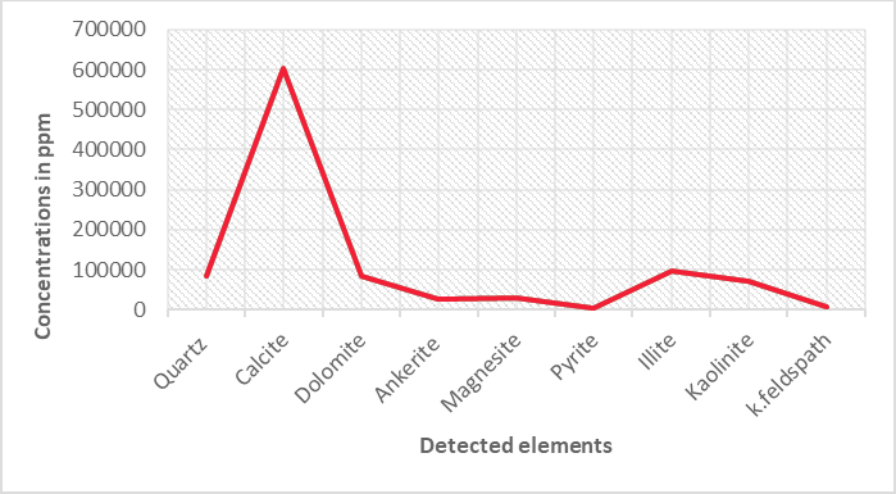

Figure 10. XRD analysis of the quarry dust sample collected at station S6

Station S6 has a relatively higher amount of quartz. Compared to other stations (8.25×10^4 ppm). In addition, trace amounts of the following minerals were detected: Siderite, Ankerite, Magnesite, Pyrite, Illite, Kaolinite, and K-feldspar. As noticed in Figure 10.

Table 3 reveals that plant and tree samples close to the quarry display elevated CaO concentrations.

Table 3. Physicochemical analysis results of the flora samples (3 plants and 3 trees)

Samples	Pine tree branch	Olive tree branch	Laurel plant	Mallows	Wild thistle	Eucalyptus leaves	Method norms
CaO, mg/kg	3500	2500	8325	3725	2925	3125	Volumetric NFT 90 005
Al_2O_3, mg/kg	22	80	75	62.5	25	70	APHA 3500 AL D
SiO_2, mg/kg	30	375	225	525	50	175	DIN EN ISO 16264-H57

Notably, the laurel plant registers 8325 mg/kg; mallows show 3725 mg/kg, and pine tree branches exhibit 3500 mg/kg. Eucalyptus leaf samples have 3125 mg/kg, and wild thistle records 2925 mg/kg. Even the olive tree branch, situated farthest from the pollution source, demonstrates a CaO mineral concentration of 2500 mg/kg. The dust covering these plants, leaves, and tree branches contains heavy metals, including aluminum. The concentration of aluminum in the olive tree branch is 80 mg/kg, in the laurel is 75 mg/kg, and in the Eucalyptus leaves is 70 mg/kg. Mallow shows a concentration of 62.5 mg/kg, wild thistle has 25 mg/kg, and the pine branch records 22 mg/kg. Numerous significant studies have emphasized the risks associated with plants' exposure to Al_2O_3, which can lead to DNA fragmentation and subsequent cell death. Additionally, it has been established that Al_2O_3 causes phytotoxicity in plant roots (Yanık & Vardar, 2015).

Regarding silicon dioxide (SiO_2), mallows exhibit the highest concentration at 525 mg/kg, followed by olive tree branches at 375 mg/kg. Then, the silicon dioxide (SiO_2) content of laurel plants was at 225 mg/kg, eucalyptus leaves (175 mg/kg), wild thistle (50 mg/kg), and pine tree branch (30 mg/kg).

Plant physiology hinges on various physiological processes crucial for growth and development, with photosynthesis standing out as the most vital. Photosynthesis entails the conversion of light energy into chemical energy, a fundamental task for the growth and survival of plants (Bhatla & Lal, 2018). The

accumulation of quarry dust on plant surfaces hampers this process as the tiny particles obstruct the penetration of light, thereby blocking the stomata, small pores on the leaves responsible for gas exchange. This interference leads to a decline in plant development and a decrease in crop quality (Meravi, Singh, & Prajapati, 2021).

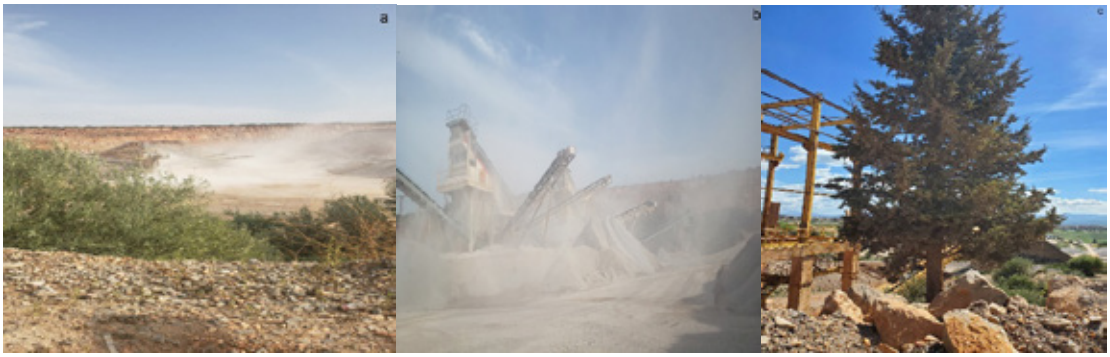

Figure 11. Dust emissions from gravel preparation operations in Heliopolis quarry (a: Air pollution caused by rock extraction and transportation; b: Dust emission from the grinding station; c: Pine tree covered by mineral dust near the crushing station)

Air pollution resulting from various gravel-processing operations in the Heliopolis aggregates quarry as we see in Figure 11a and Figure 11b has extended to neighboring plants and trees, causing a change in color and a reduction in productivity. Physical and chemical analyses have confirmed that the mineral dust covering the plants and trees in this area hinders their natural development and obstructs sunlight, significantly affecting the process of photosynthesis.

We can observe the visible impact of quarry dust on the pine tree with the naked eye in the attached picture in Figure 11c.

Table 4 presents the findings of the physicochemical analysis, and it reveals an aluminum concentration in the water samples of 0.50 mg/l while the World Health Organization has set a limit of 0.05 mg/l to 0.2 mg/l for aluminum in drinking water.

Table 4. Water sample physicochemical examination results

Parameters	Values	Method norms
PH at 25°C	7.74	NF T 90-008
Conductivity (CE) µS/cm at 20°C	749	NF T 90-031
Salinity mg/l at 20°C	334	NF T 90-031
Aluminum (Al) mg/l	0.50	APHA 3500 AL D
Silica (SiO_2) mg/l	0.30	DIN EN ISO 16264-H57
Calcium oxide (CaO) mg/l	170	Volumetric NFT 90 005

Health studies underscore the dangers associated with the presence of this chemical element (Al) in water, linking it to various incurable diseases such as Alzheimer's and other neurological disorders (Hızlı, Karaoğlu, Gören, & Kobya, 2023). Exposure to aluminum poses health risks for individuals across age groups, including children, adults, and the elderly and even animals. (Niu, 2023). A 15-year study conducted in the south of France found a correlation between the consumption of water containing aluminum at concentrations greater than or equal to 0.1 mg/day and the onset of dementia. Additionally, the analysis in Table 4 reveals the presence of silicate at 0.30 mg/l and a significant amount of CaO at 170 mg/l.

Table 5. Physicochemical Analysis Results of Soil Samples

Parameters	Values	Method norms
pH at 25°C	9.51	AFNOR : X 31--103
Conductivity (EC) µS/cm at 20°C	457	ISO : 11265
Salinity mg/l at 20°C	217	ISO : 11265
Calcium oxide (CaO) mg/kg	9350	Volumetric NFT 90 005
Aluminum (Al) mg/l	82.02	APHA 3500 AL D
Silica (SiO_2) mg/l	175.18	DIN EN ISO 16264-H57

According to the physicochemical analysis of soil samples presented in Table 5, it is evident that the soil contains significant concentrations of CaO mineral (9350 mg/kg), aluminum (Al) with a concentration of 82.02 mg/kg, and silicon dioxide (SiO_2) with 175.18 mg/kg.

The scarcity of water, amidst global water shortages, combined with the presence of aluminum in the soil, contributes to environmental contamination, ultimately causing stress for plants and leading to a decline in their growth (José Rodrigues Cruz, 2023).

Land degradation and loss of vegetation cover are some of the harmful effects of quarrying activities. Plants are crucial in stabilizing soil and supporting ecological life (Opondo, Ajayi, & Makindi, 2022), which is vital for robust food production. Unpolluted soil plays a significant role as a preserver of water and life. However, soil contamination by substances like heavy metals and industrial waste leads to premature deaths and the transmission of diseases. Soil pollution also restricts the presence of microorganisms, leading to increased toxicity. Hence, contaminated soil is likely to cause groundwater contamination in the future (Münzel, Hahad, Daiber, & Landrigan, 2022).

CONCLUSION

Our research revealed that various methods of preparing gravel adversely affect air quality, leading to pollution. Monitoring of air quality indicated that particulate matter emissions from gravel extraction activities exceeded the maximum limits set by the World Health Organization for PM2.5 and PM10, with readings of PM2.5 at 520 µg/m^3 and PM10 at 684 µg/m^3 in S2. Inhaling fine mineral particles like PM2.5 heightens the risk of lung cancer and respiratory ailments such as asthma, whereas PM10 can cause skin irritation, conjunctivitis, and eye infections. The wind transports these tiny particles that contain a variety of minerals such as calcite, dolomite, quartz, aluminum oxide, iron oxide, silicon dioxide, and other mineral oxides, posing significant risks to local populations, particularly vulnerable groups like the elderly and pregnant women. The physicochemical analysis conducted on water, soil, and flora samples validates the transportation of these particles by wind to neighboring regions, potentially leading to damage and a reduction in crop quality. In summary, quarrying activities must take proactive measures to mitigate various forms of pollution. Emphasizing the significance of incorporating these findings is crucial for protecting the environment and fostering cleaner production practices for aggregates in the future.

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Conflict of Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
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Ethics Statement
Our research preparation did not involve human or animal experiments.
All authors have read and approved the final version of the manuscript and agree with its submission to the journal: Quality of life.

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Modeling and Visualization of Noise Levels Near Mining Operations

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ABSTRACT: The study presents an in-depth analysis of the impact of noise from mining operations, focusing on the spatial distribution of noise levels and their compliance with regulatory limits. Utilizing advanced modeling and visualization techniques, it demonstrates effective noise management strategies that ensure compliance with national regulations. Findings highlight the importance of integrating environmental assessments and technological innovations in mitigating noise pollution, underscoring the mining industry's commitment to sustainable practices and community well-being. This research contributes valuable insights into environmental management, offering a model for balancing industrial activities with ecological and health considerations. Key findings emphasize the significance of integrating environmental assessments and technological innovations to mitigate noise pollution, showcasing the mining industry's commitment to sustainable practices and community well-being. The study underlines the importance of noise management strategies that align with national regulations to protect both the environment and public health. Using advanced modeling and visualization techniques, the research offers valuable insights into environmental management, presenting a model for balancing industrial activities with ecological and health considerations. It contributes significantly to the understanding of noise pollution in the mining sector, proposing effective solutions for its control. This work is grounded in a broad review of literature on environmental pollution and specific studies on noise pollution's effects on health, highlighting the broader context of industrial and urban noise sources. It presents a detailed analysis of noise levels around a specific mining operation, including modeling and visualization of noise propagation and its impact on surrounding residential areas. The conclusion drawn from this study is that through strategic planning, technological interventions, and adherence to regulations, mining operations can effectively mitigate noise pollution. This ensures that noise levels remain within acceptable limits, thereby minimizing their impact on nearby communities and contributing to a safer and more sustainable mining environment.

Keywords: noise, modeling, visualization, mining

INTRODUCTION

Every day, the environment is more polluted with different types of pollutants due to the constant development of industry, traffic and other anthropogenic activities (Barbosa et al., 2008; Gašić et al., 2010; Lammel et al., 2010a, 2010b, 2011; Ilić 2015; Ilić et al., 2018a, 2019a, 2020a, 2020b; Wang et al., 2020; Ilić and Maksimović, 2021; Zhanibekov et al., 2022; Radović et. al 2022; Ilić et al., 2021a, 2021b; Ćirišan et al., 2023; Popović and Ilić, 2023a, 2023b). In the 20th century, due to accelerated, unilateral, and uncontrolled technological development, significant depletion of natural resources, increase in the Earth's population, insufficient knowledge about the environment, and disregard for ecological ethics, large amounts of waste and other polluting substances were emitted into the natural environment, significantly degrading it. (Nešković Markić et al., 2019; Stojanović Bjelić et al., 2022a; Ilić et al., 2021a, 2021b, 2021c, 2021d; Ilić et al., 2022; Ilić and Maksimović, 2021; Stojanović Bjelić et al., 2022b; Ilić et al., 2023a). Unaltered and preserved natural environments are increasingly scarce, while human activity zones are continuously expanding, and within them, the conditions for living and working cease to meet the most basic requirements of ordinary life (Ilić and Maksimović, 2021; Ilić, Govedar, Trkulja, 2023). All unwanted changes in

the physical, chemical and biological properties of the basic components of the environment that adversely affect life by disrupting ecological systems are labeled as pollution, and appear in the form of pollutants (substances, fields) or pollutants in different components of the environment (Ilić et al., 2012; Luković et al., 2018; Ilić et al., 2018a, 2018b; Fino 2019; Ilić et al., 2019a, 2019b; Ilić et al., 2022; Ćirišan et al., 2023; Popović and Ilić, 2023; Farooqi et al., 2023; Ilić et al., 2023a, 2023c; Nešković Markić et al., 2023; Stojanović Bjelić et al., 2023).

Environmental noise represents one of the key problems of modern society (Popović et al., 2024), with a wide range of sources and impacts on people's health as well as their overall well-being. Diversity of noise sources including traffic, industrial activities, construction works and urban operations Farooqi et al., (2022), has significant socioeconomic consequences that require more effective control strategies. These authors discuss the types of noise in detail, identifying key sources and suggesting its measures in order to mitigate its impact on the community. The work of Ilić et al., (2021e) focuses on the determination, mapping and prediction of noise pollution, providing a methodology for the analysis and management of noise in urban environments. Similarly, Božić et al., 2020 investigate noise levels in modern urban intersections, while Ilić et al., 2012, 2017, 2018c, 2018e, 2018e, 2018f and Božić et al., 2018) consider traffic noise levels in the city of Banja Luka , providing valuable data on urban noise pollution. Additional studies, such as the work by Stojanović Bjelić et al., 2022 b), deal with noise in the environment with a special focus on thermal power plants. Janjuš et al., (2015a, 2015b) analyze noise generators in the City of Banja Luka and the municipality of Kotor Varoš, contributing to a broader understanding of the noise problem and its economic aspects. Noise pollution, defined as unwanted or harmful outdoor sound, has emerged as a significant environmental and health issue in modern societies. Its sources are diverse, ranging from industrial activities, transportation systems, construction works, to various recreational activities. Among these sources, mining operations represent a particularly intensive contributor, due to the nature and scale of the activities involved. Faster and more extensive creation of goods, construction of new transport links and more diverse application of auxiliary means and devices in all branches of life (especially in industry and mining) and many other factors that keep pace with modern society enable the comfort of life, but at the same time affect the endangerment of people's health. The negative consequences of such a modernized life, such as noise and non-ionizing electromagnetic radiation, can cause complex damage of human health, occur in industrially developed cities but also in urban areas in general (Popović and Ilić, 2023a, 2023b).

Environmental noise pollution is a pervasive component of the urban landscape, contributing to a range of adverse health states. The World Health Organization (WHO) has identified environmental noise as a significant threat to public health, second only to air pollution among environmental hazards (WHO, 2018). It is associated with various health risks including hearing loss, cardiovascular diseases, cognitive impairment in children, sleep disturbances, and a general reduction in quality of life (Basner et al., 2014).

Research by Farooqi et al., (2021), provides insight into urban noise and its non-auditory health effects on residents, highlighting significant effects of noise to the quality of life in urban areas. Obtained findings are consistent with the study of Farooqi et al., (2020), which deals with the assessment of noise pollution and its effects to the human health, showing that noise is not only an urban problem, but also a challenge in industrial zones. The effects of the harmful impact of noise on human health are varied, from psychological manifestations to irreversible damage to the sense of hearing (Popović and Ilić, 2023).

Mining operations, essential for extracting valuable minerals and resources, significantly contribute to local and regional noise pollution levels. The processes involved in mining, such as drilling, blasting, crushing, and material transportation, are inherently loud and can generate noise levels exceeding 85 decibels (dB) near the noise sources. For instance, studies have shown that noise levels near drilling sites and

during blasting operations could reach levels harmful to human health, necessitating comprehensive noise management strategies (Dzhambov, 2015). The health impacts of noise pollution from mining operations are profound, particularly on workers and nearby residents. Workers are at an increased risk of noise-induced hearing loss (NIHL), one of the most common occupational illnesses in the mining industry. Furthermore, communities living in proximity to mining sites may experience disturbances in daily activities, reduced quality of life, and increased risks of cardiovascular diseases due to elevated noise levels (Niemann et al., 2006). Addressing noise pollution from mining operations requires a multifaceted approach, including technological, regulatory, and community engagement strategies. Technological solutions involve the use of quieter machinery, sound barriers, and the strategic planning of mine site operations to minimize noise emissions. Regulatory approaches include the establishment of noise level standards, monitoring compliance, and implementing zoning regulations to protect residential areas from excessive noise. Community engagement is also crucial in developing and implementing noise mitigation strategies, ensuring that the concerns of affected populations are addressed (Hammer et al., 2014). Noise pollution remains a critical environmental and public health challenge, with mining operations contributing significantly to the issue. Through a combination of technological innovations, regulatory frameworks, and community engagement, it is possible to mitigate the adverse effects of noise pollution and protect the health and well-being of workers and communities.

This work aims to explore the multifaceted aspects of noise pollution, with a special focus on the implications of mining operations. Here is given assessing of the noise level at the surface of the mine and its impact over the surrounding population. Modeling and visualization of noise levels around surrounding objects will be done in the work.

MATERIALS AND METHOD

Location

The subject of the research noise influence originated from surface mine Ostružnja, Stanari. South part of mine basin was examined known as Ostružnja deposit, while the south part of basin is known as deposit Raškovac. Ostružnja belongs to the Stanari municipality, in vicinity of railway and main road which connected Doboj and Prnjavor. Municipality Stanari is placed at favorable geographical position, while in accordance to the terrain configuration this area a fairly homogeneous space in size of 161 km^2. The territory of the Stanari is neighboring by the municipalities of Teslić, Tešanj, Doboj, Prnjavor and Derventa. The relief of the residential area is mostly slightly hilly and hilly with the highest altitude of 343 m and the lowest 138 m.

The model used for assessment of noise level

In order as possible faithfully presentation of the noise level, a noise map was constructed, and the results obtained via calculations were projected onto the Google map. These projections on the Google map were preceded by the drawing of clear boundaries of the front of the pit of the surface mine Ostružnja with accordance to the project documentations. According to the plan, the solid black line on map labeled the boundary of the mine, which represents the exploitation front, behind are populated areas where noise propagation is examined. The space between the white and black solid lines represents the intended protective belt of greenery, chosen in order to protect populated areas against the noise, dust, or unexpected collapse of the rim during mining operations. (Figures 1, 2, 4, 6, 8, and 10).

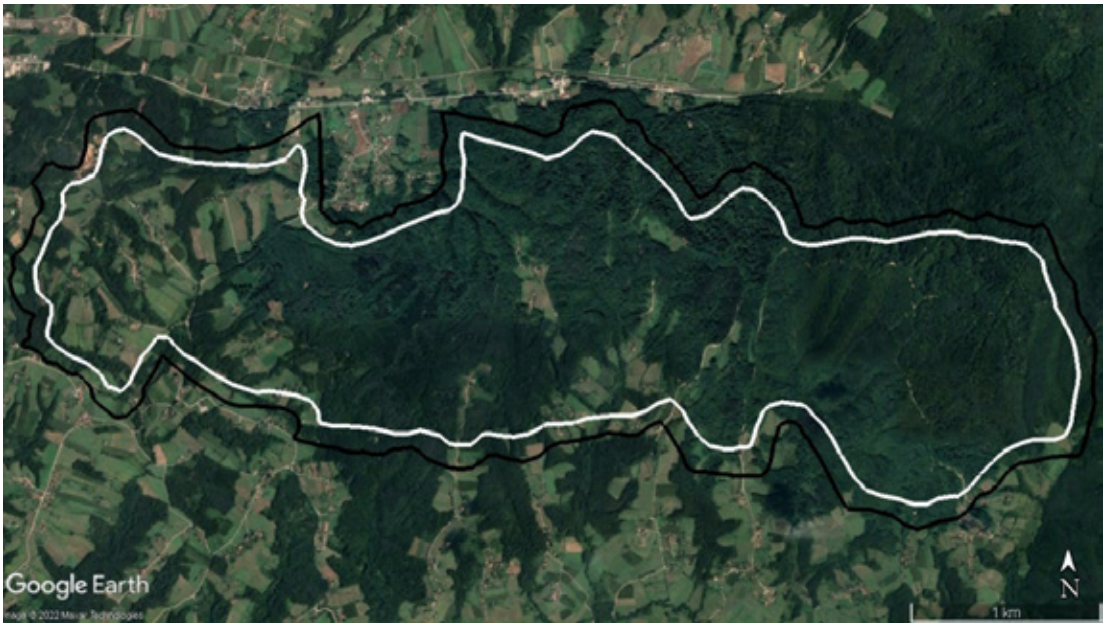

Figure 1. The black solid line represents the exploitation front. The area between the black and white lines is the noise protection zone created of the Ostružnja surface mine

The main source of noise is transportation and discontinuous heavy machinery, used for exploitation in the mine, for which it is envisaged to move or set up along the entire length of the mine boundary (along the white line). The most unfavorable case is considered when there is the spread of noise from dynamic sources, generated by excavators that produce the highest noise level in the amount of 90 dB, but also by other moving machinery which is also taken into account. Assessed length of the mine front border, where is expected exceed noise level at the mine is 17191 m.

We done an effort to assess the noise level over the target populated area objectively as is possible, where heavy machines are taken into account and considered their full contribution. This is taken as a part of discontinuous mechanization, that are placed in the more prominent parts of the mine surface on the very perimeter, on the shortest distance from the populated areas, which achieves the maximum contribution to the noise level of these machines in settlements and assumes the most unfavorable scenario. Spreading of the sound is followed by damping caused by various physical effects including friction, temperature but humidity which causes more absorption of sound energy. Amount of attenuation index of the noise accounted for its spreading through air in the calculation is $\Delta L_{air} = 2\ dB$ (Wunderli et al., 2016).

Used calculation model is simple free space analysis, where is considered the propagation of sound that does not encounter a physical obstacle. Follow this, the assessment was made for extreme case, which is the beginning of the implementation of the works, when heavy mobile machines are on the surface intended for the formation of the mine in the level of inhabited buildings. In the theoretical assessment of the noise level it is assumed that the transportations speed of moving is constant, and that their activity is twice as lower in the periods defined as evening and night according to national regulation (Regulation 2/23).

In accordance with the current national regulation (Regulation 2/23), given investigation zone belongs to the IV category that could contain: commercial, business, residential buildings with traffic corridors. For this zone, the daily, evening and night limit noise levels are 65 dB, 65 dB and 50 dB, respectively. The maximum equivalent value of the noise level in the vicinity of the mine was obtained taking into account that 10 heavy transport machines (excavator and dumper type) and all discontinuous machinery,

listed in the table below, are active there daily, while the activity of all machines is reduced twice during the evening period and at night. Noise levels measured at a standard distance from heavy machinery deployed over the mine surface, whose harmfull contribution is expected in a populated area. List of masihnes deployed on minte is given in (Table 1) along with noise level they produce at referent values of 7.5 m distant, from where they could be considered in the calculation model as a point sources.

Table 1. Overview of heavy machinery and their distribution across the mine along with noise levels they produce, measured at a standard distance from each one d_0

Machine	Noise level in dB
Crusher	89
Tanker	70
Skip	80
Grader	80
Dumper	80
Bulldozer	80
Loader	85
Excavator	90
Self-propelled transporter	83
Rotary excavator	80
Procrastinator	72

The method of noise level calculation

Overview of the basic quantities, concepts and methods according to which the given assessment was performed are in accordance with the appropriate technical standard according to national regulation (Regulation 2/23). Noise level in the point (x, y) genarated by the source labeled with index i in the moment t_j postioned at (x_i,y_i), is given by next exression:

$$L_i(x,y,t_j) = L_0 + 10\log_{10}\frac{{d_0}^2}{(x_i-x)^2+(y_i-y)^2}$$

where L_0 is sound level of vehicle, according to the standard calculations (Du et al., 2021) measured at referent distance d_0 = 7,5 m. Average contribution to the noise level at each point of the observed location, caused by the uniform movement of mobile heavy machinery along the mine roads, was taken into account. If there are several heavy machines (m total number) at the location, their total contribution to the noise level at each point of the space at a given moment is summarized as follows:

$$L(x,y,t_j) = 10\log_{10}\sum_{i=1}^{m} 10^{0,1L_i(x,y,t_j)}$$

Equivalent noise levels (L_{eq}) are obtained by averaging the loudness over time, at each point of the surface, as well as taking into account all possible contributions comming from heavy machines, whose work is foreseen on pile 3. These time averaging calculations were performed in according to the relation

$$L_{eq}(x,y) = 10\log_{10}\frac{1}{T}\int_0^T 10^{0,1L(x,y,t)}dt$$

where TT is the full time of movement of the transport vehicle along the path with the greatest predicted contribution to the noise level in populated areas.

RESULTS AND DISCUSSION

Noise map

Based on the data obtained regarding the schedule of mining machinery, the number of heavy machines their distribution and the planned position of the mine, noise levels at the mine surface, its nearest residential areas, and beyond have been estimated. The studied mine covers a large area, with a perimeter of 17.2 km; therefore, to objectively present the noise levels in the field in directly exposed residential parts, the map needs to be devided on segments and results should be displayed partially to ensure clear and quality visibility of the exposure of residential area, and with it, an assessment of noise levels within them. For this purpose a total of 5 projections for different segments of the mine, which include residential areas, were made. The computationally obtained values were projected onto Google maps, resulting in noise maps, to provide as accurate a depiction as possible of the noise load in residential areas during the day and night. Assuming that the highest noise level will be during the beginning of excavation, while heavy machinery is at the level of residential areas, the dominant source of noise, the "hotspot," becomes the boundary belt, located 50 m from the mine's edge on the maps marked with a white line along which heavy machinery will be placed during the indicated phase. The green belt, on maps recognized as area between the black and white curve, serves for sound attenuation and stopping the spread of dust. To substantiate these observations, recent studies such as Pantelić et al., (2023) have underscored the significance of environmental noise impact assessments in large-scale mining operations, emphasizing the necessity of integrating noise control measures into mine planning to mitigate adverse effects on nearby communities. Similarly, Li et al., (2021) have demonstrated through simulation experiments the tangible impacts of noise on miners' safety behavior, further illustrating the critical need for effective noise management in mining environments. Moreover, research by Lokhande et al., (2018) on the upsurge of noise pollution due to open-cast mining activities has highlighted the value of utilizing modeling and mapping tools for a more faithful representation of noise exposure levels in residential areas adjacent to mining sites.

The noise field, represented by contour plots, illustrates the computationally predicted spatial distribution of noise levels, derived from a model previously described, highlighting areas exposed above and below the threshold values prescribed for day and night (Morillas et al., 2018). Reducing the intensity of heavy machinery operation at night narrows the zone where intensity exceeds the threshold and expands the area with lower sound levels (Verbeek, 2018). The contour plots are transparent, allowing all features of the Google map, including residential and other buildings, fields, forests, and roads, along with a black line denoting the boundary beyond which noise levels in residential areas are assessed, to be clearly visible. The color of each point on the image corresponds to the noise intensity at that specific real-world location as captured from satellite imagery (maps), which can be interpreted using the dB scale provided with each contour plot or along the contours on the image (Zipf et al., 2020). The analysis covers a wide belt that includes residential and other ancillary buildings of rural households, while uninhabited areas (forests, pastures) are not included.

Figure 2. The first examined segment of the mine front, 2317 m long, with proposed measuring points, next to residential areas near the potentially most affected by emitted noise from heavy machinery

Areas of different colors on the provided images represent surfaces exposed to various noise levels, expressed in dB, as described in the legend of the plots. Residential buildings, located behind the front of the mine (black line) whose exposure is assessed, fall within a zone where, during the mine's daytime operational regime, image under a), the maximum predicted noise is below 60 dB, while during the evening and night, image under b), the maximum intensities do not exceed 50 dB. This means that during the two operational regimes, the noise values during all three analyzed periods (day, evening, and night) are within the limits defined by national regulation (Regulation 2/23) for Zone IV, to which this area belongs.

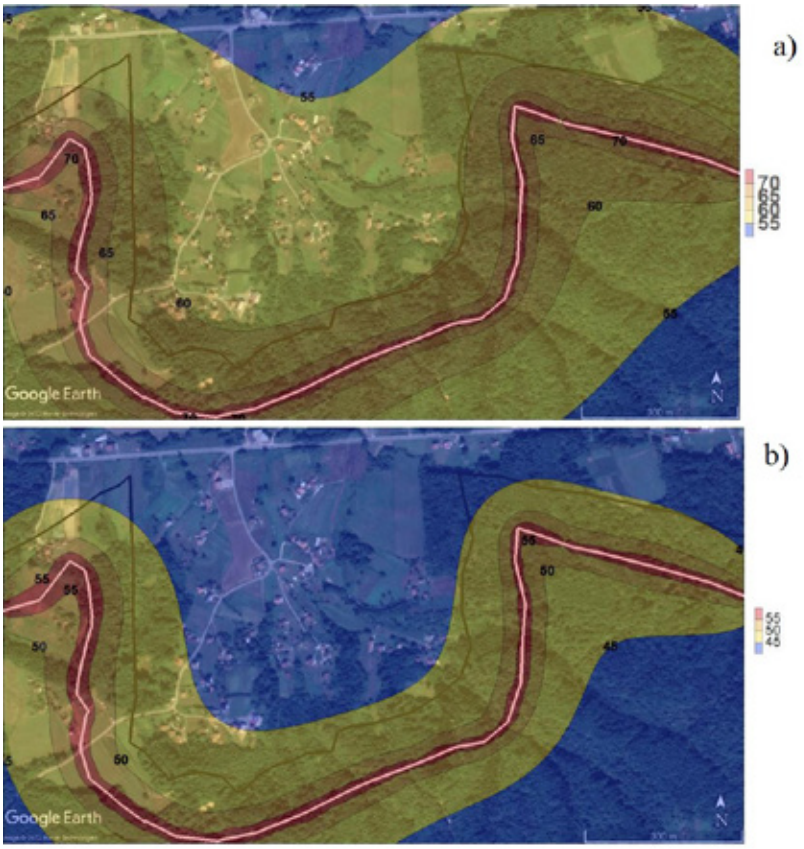

Figure 3. The first examined segment of the mine front of 2317 m length, with different colored areas with various noise levels, defined on the scale right

For the first partial segment, noise intensity exceeding according to the valid threshold values for category IV periods is not anticipated. Nowhere in the first segment, on the surface behind the black line, i.e., behind the front of the mine, during the day, the value of 60 dB is exceeded, also during the evening and night, the noise level does not exceed 50 dB. This means that during the two work regimes, the noise values during all three analyzed periods (day, evening, and night) are within the limits defined by national regulation (Regulation 2/23) for Zone IV, to which this area belongs. The studies by Peterson (2018) and Madahana et al., (2019) provide evidence supporting the effectiveness of noise management strategies in mining operations, ensuring that noise levels remain within legal limits to protect the health and safety of mine workers and nearby residential areas.

Figure 4. The second examined segment of the mine front of 2938 m length, with proposed measuring points next to residential buildings near the mine, potentially most affected by noise

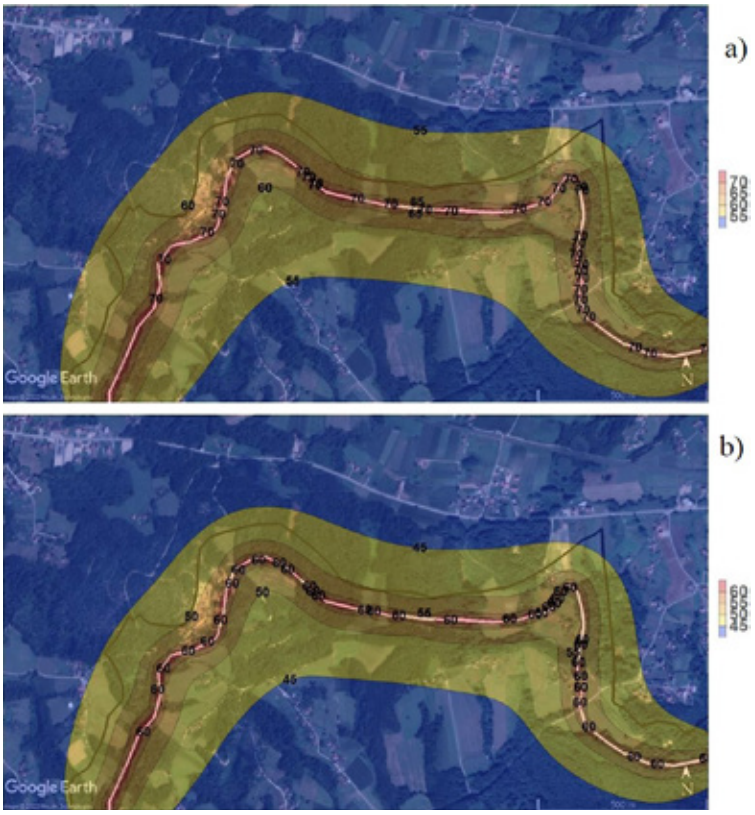

Figure 5. The second examined segment of the mine front of 2938 m length, with the different colored area exposed to various noise levels, defined on the scale on right

Calculations performed for noise spreading simulations in second segment, shown that there is no anticipated exceedance of noise levels according to the valid threshold values of Regulation 2/23 for periods defined for category IV. Nowhere outside the contour of the second segment, outlined by a black line, during the daytime period is the value of 60 dB exceeded, and during the evening and night, the level does not surpass 50 dB. This compliance ensures that during both operational regimes, the noise levels during all three analyzed periods (day, evening, and night) remain within the limits defined by national regulation (Regulation 2/23) for Zone IV, to which this area belongs.

Figure 6. The third examined segment of the mine front, 3195 m long, with proposed measuring points, next to residential area, close to the mine potentially most affected by noise

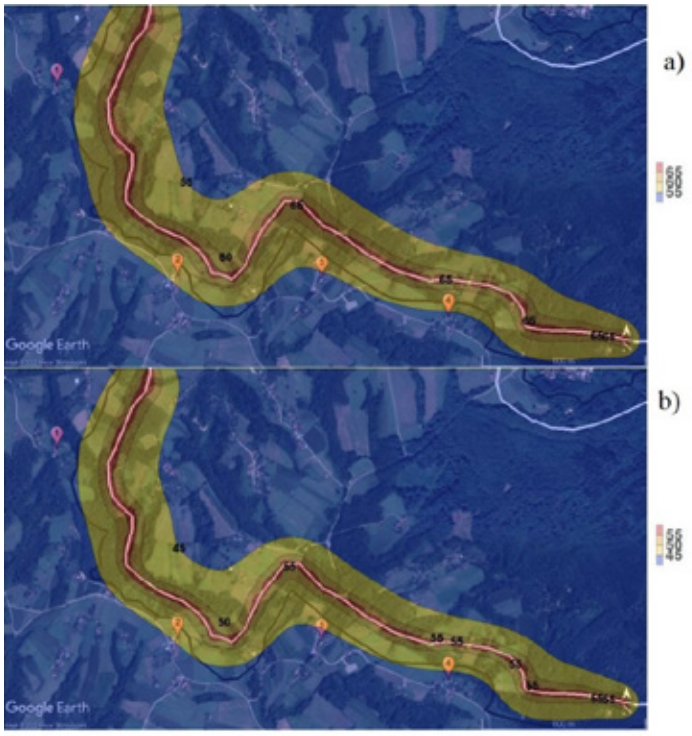

Figure 7. The third examined segment of the mine front of 3195 m long. The different colored areas are exposed to the noise of the level values given on the scale to the right side

The analysis for the third partial segment predicts that the noise levels will comply with the thresholds established by Regulation 2/23 for category IV. Within the third segment, beyond the black line or the front of the mine, the noise does not exceed 60 dB during the day, and remains below 50 dB during the

evening and night, ensuring adherence to environmental standards and minimizing disturbance to surrounding areas.

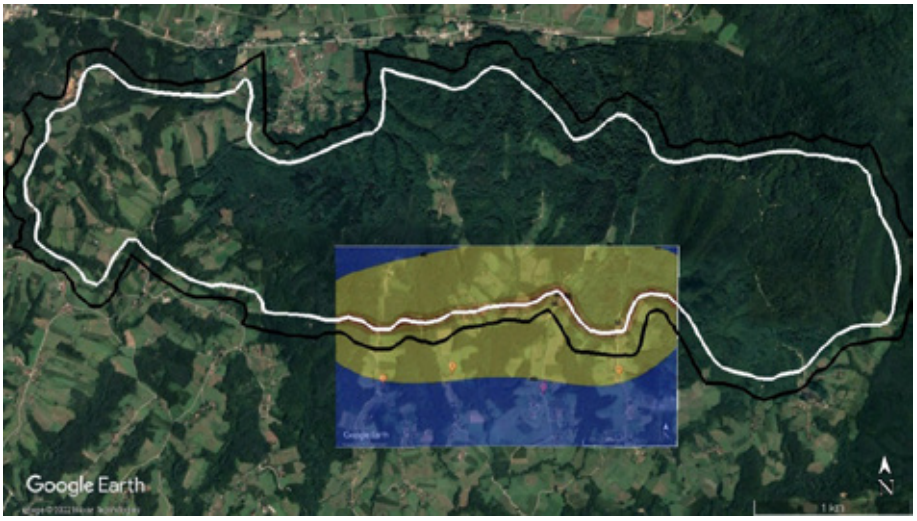

Figure 8. The fourth examined segment of the mine front of a 2773 m length and proposed measuring points, next to residential area near the mine, potentially most affected by noise

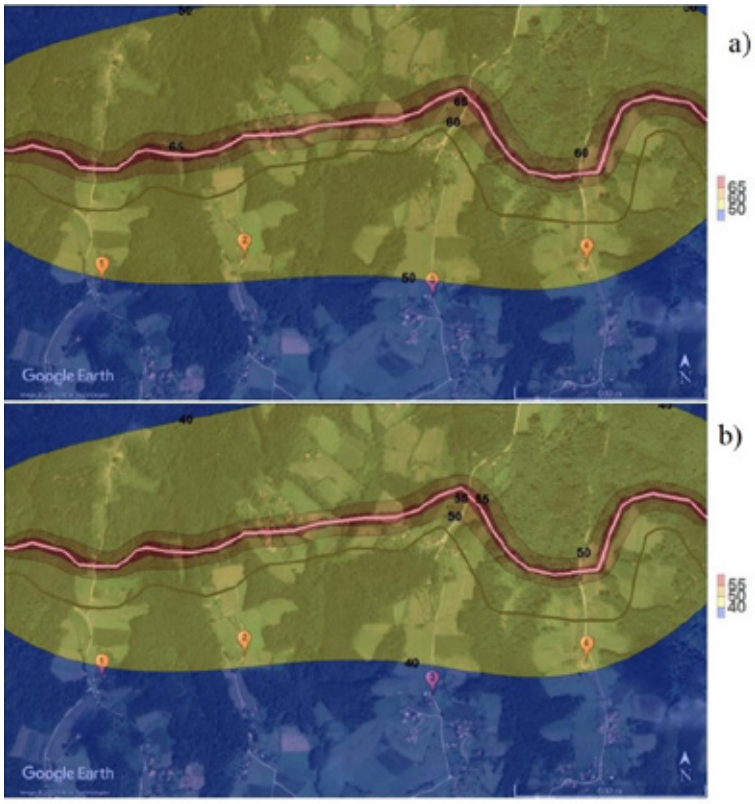

Figure 9. The fourth examined segment of the mine front is 2773 m long. The different colored areas are exposed to the noise levels given on the scale to the right side

The analysis for the fourth segment indicates that noise levels will remain within the limits established by Regulation 2/23 for category IV. Specifically, outside the boundaries of the fourth segment, marked by a black line, where noise level does not exceed 60 dB during daytime but also remains below 50 dB during evening and nighttime hours. This compliance demonstrates the effectiveness of noise control measures in maintaining environmental standards and safeguarding the well-being of nearby communities.

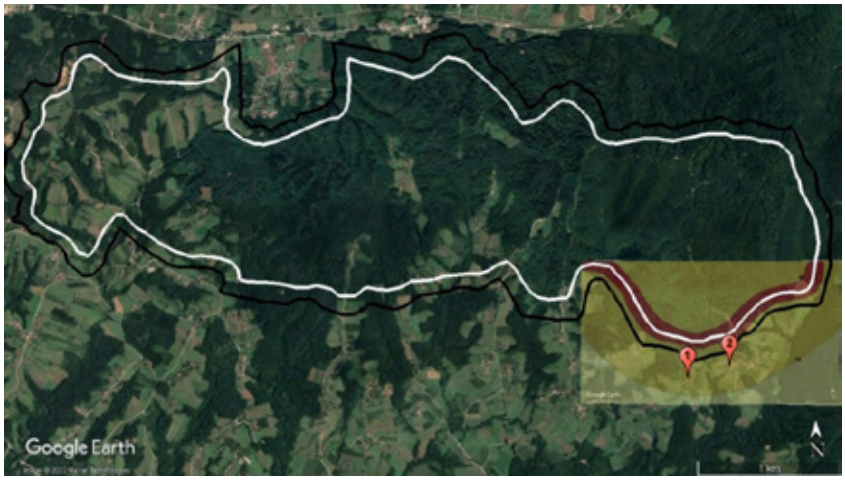

Figure 10. The fifth examined segment of the mine front of 2645 m length, with proposed measuring points, next to residential buildings near the mine, potentially most affected by noise

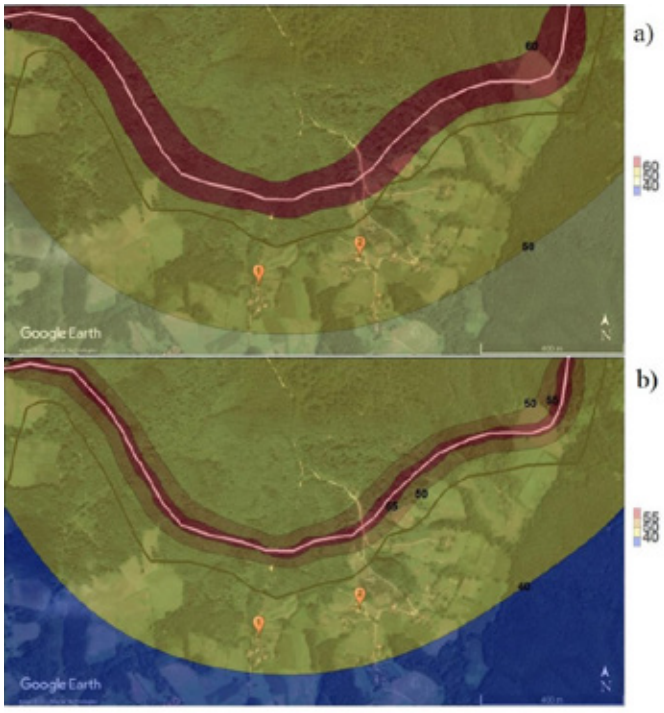

Figure 11. The fifth examined segment of the mine front is 2645 m long with the levels of noise and associate scale on right side

The analysis for the fifth segment predicts that noise levels will not exceed the limits set by Regulation 2/23 for category IV during any period. Specifically, outside the contour of the fifth segment, in front of black line, the noise level does not surpass 60 dB during the day but also stays below 50 dB during the evening and night. This indicates effective noise management strategies are in place, ensuring compliance with established environmental standards and minimizing the impact on surrounding areas.

In the analysis and discussions surrounding the management of noise pollution in mining operations, it becomes evident that addressing this challenge requires a multidisciplinary approach, combining regulatory compliance, technological innovation, and continuous monitoring. The calculated predictions for various segments of mining operations underscore the efficacy of current noise management strategies in adhering to established environmental standards, notably national regulation (Regulation 2/23) for cat-

egory IV, ensuring that noise levels remain within acceptable limits both during the day and at night. These findings align with recent research that highlights the critical role of environmental impact assessments and the application of advanced modeling and mapping tools in mitigating noise pollution (Pantelic et al., 2023; Li et al., 2021; Lokhande et al., 2018).

Moreover, the inclusion of advanced noise prediction software tools and the adoption of comprehensive noise control measures further demonstrate the mining industry's commitment to reducing the adverse impacts of noise on workers and nearby communities (Lokhande et al., 2018). The continuous effort to maintain noise levels below the threshold of 60 dB during the day and 50 dB at night reflects an adherence to best practices and regulatory requirements, contributing to a safer and more sustainable mining environment.

Based on the presented results, the limit exposure during the daytime period for the area that belongs category IV, on the noise maps 3, 5, 7, 9, and 11 under a) was not exceeded anywhere (Figures 3, 5, 7, 9 and 11). All populated areas during this period are exposed to a noise level below 60 dB. During daytime operation within the planned protection zone of the mine, the sound level does not exceed the limit value of 65 dB. Therefore, based on the obtained data, according to the described model, it can be concluded that the noise level in populated areas during the daily working regime of the surface mine Ostružnja is below the level limits prescribed for the zone IV. During the evening and night periods, which coincide with the night mode of mine operation, on the noise maps 3, 5, 7, 9, and 11 shown above under b) (Figures 3, 5, 7, 9 and 11), it can be seen that the intensities in populated areas do not exceed the limit values defined by the national regulation (Regulation 2/23), i.e. are less than 50 dB.

CONCLUSION

The research results of modeling and visualization of noise levels in the vicinity of mining operations provide a significant contribution to the understanding of the impact of industrial activities on the quality of the environment and the health of local communities. The application of advanced modeling and visualization techniques enabled the identification of key zones with significant noise exposure. The research confirms that noise from mining operations is a relevant source of pollution, with far-reaching consequences for human health and well-being, highlighting the need for integration of environmental impact assessments and technological innovation in order to reduce noise pollution. The research also points to the importance of adopting comprehensive noise management strategies, including technological solutions, regulatory approaches and community engagement. Implementation of quieter machinery, use of noise barriers, strategic planning of mine site operations, and regulatory frameworks that set standards for noise levels, are key elements for effective noise management. Community engagement and transparency in communication are essential for development and implementation of noise mitigation strategies that adequately address the concerns of affected populations. This research demonstrates that through a combination of technological innovation, regulatory frameworks and community engagement, it is possible to mitigate the negative effects of noise from mining operations and protect the health and well-being of workers as well as local communities. Considering the complexity of the noise issue and its impact on various aspects of the environment and human health, future research should focus on the development and evaluation of new technologies and methodologies for noise assessment and management, as well as on further understanding of the long-term effects of noise on human health. Effective noise management in the context of mining operations is a key aspect of sustainable development, requiring a multidisciplinary approach and synergy between researchers, industry and decision makers. This research provides an important framework for considering future strategies and policies aimed at minimizing the impact of noise from mining like other

industrial operations too on the environment and society.

Based on the previous analysis, it's evident that strategic planning and technological interventions have effectively mitigated noise pollution within regulated limits across various operational phases and segments of mining activities. The study conclusively demonstrates that the application of noise mapping, predictive modeling, and the implementation of noise attenuation measures, mining operations can coexist with residential areas without exceeding the noise thresholds established by environmental regulations. This represents a significant advancement in balancing of industrial activities with environmental stewardship and community well-being.

Conflict of Interest
The authors declare no conflict of interest.

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The Antifungal Properties of a Fresh Extract Derived from *Allium Sativum*

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ABSTRACT: Many fungal species are opportunistic and rarely pathogenic to healthy individuals unless dealing with an immunocompromised host. There are numerous reasons why a host might be immunocompromised (HIV, AIDS, TB, leukemia, diabetes, and many other causes), as well as therapies with antimicrobial drugs, corticosteroids, immunosuppressants, etc., which act immunocompromising on the host's immune system. Such conditions favor opportunistic systemic fungi that will seize the opportunity to colonize the weakened organism, which is not prepared and strong enough to fight off the infection. Aspergillosis, candidiasis, and other fungal diseases are typical examples of opportunistic systemic fungal infections. This study aims to assess the antifungal potential of fresh *Allium sativum* extract originating from the Republic of Srpska in comparison with clotrimazole against two isolates of *Candida albicans*, one reference strain of *Candida albicans* WDCM00053, *Saccharomyces cerevisiae* WDCM3058 and *Aspergillus brasiliensis* WDCM00054. The results of the study showed that fresh *Allium sativum* extract has higher antifungal activity against *Candida albicans*, *Saccharomyces cerevisiae*, and *Aspergillus brasiliensis* compared to clotrimazole, a standard antifungal drug.

Keywords: *Allium sativum*, antifungal properties, clotrimazole

INTRODUCTION

Fungal infections represent a significant health problem and most commonly occur as a result of weakened immunity. Their frequency depends on various factors, including the individual's immune status, the presence of other underlying health issues, and environmental factors. The most common fungal infections include those affecting the skin, nails, and mucous membranes. Serious systemic fungal infections often occur in individuals with compromised immune systems, such as those with HIV, organ transplants, serious illnesses, or after antibiotic therapy, leading to various pathological conditions (Yang et al., 2006; Nantz et al., 2011; Lockhart et al., 2019).

Candida albicans is naturally present in the human body, and commonly found in the mouth, intestines, and genital area. However, when the balance of microorganisms is disrupted, *Candida albicans* can cause infection. It most commonly presents as vaginal candidiasis in women but can also affect other parts of the body, including the mouth and skin. These infections often occur in individuals with weakened immune systems, diabetes, or after antibiotic use (Pfaller & Diekema, 2007; Castanheira et al., 2016).

Saccharomyces cerevisiae is the most useful type of yeast, better known as baker's yeast, used in traditional or industrial bread, beer, or wine production. It can be found as a harmless and transient commensal and colonizer of mucosal surfaces in healthy individuals. It is often present in the human gastrointestinal tract and is usually beneficial, aiding in digestion. However, in individuals with weakened immune systems, such as those with serious illnesses, it can cause infections, although such cases are rare (de Llanos et al., 2011; Pérez-Torrado & Querol, 2016; Lockhart et al., 2019).

The genus *Aspergillus* is responsible for about 75% of cases of otomycosis, with *Aspergillus brasiliensis* being the most common causative agent. *Aspergillus brasiliensis* is an opportunistic pathogen that becomes pathogenic when the first line of defense is breached, such as in individuals with weakened immune systems (Cairns et al., 2018; Cornelia Lass-Flörl, 2019). It is used in industry to produce enzymes and metabolites.

In the treatment of fungal diseases, only a few classes of antifungal drugs are available, making treatment difficult due to multidrug resistance. Since fungi are eukaryotes, like humans, manipulating fungi and treating them is more challenging. Eukaryotic organisms, unlike prokaryotic organisms, have much more complex molecular processes and cell structures, which are the main reasons why there are no broadly effective antifungals, and why each fungal infection requires aggressive and prolonged therapy (Perlin et al., 2017).

The antifungal nature of plant products has been determined by the presence of flavonoids, phenols, saponins, tannins, and terpenoids and the mechanism of action of such molecules involves inhibiting the fungal cell membrane and hyphal progression (Suurbaar et al., 2017; Silva et al., 2010)

Allium sativum has wide applications in human nutrition and scientific research due to its biological properties. In traditional medicine, it is used as a remedy for treating bacterial, fungal and viral diseases (Martins et al., 2016; El-Saber Batiha et al., 2020; Genatrika et al., 2020). It helps maintain healthy microbiomes in the gastrointestinal tract by removing harmful bacteria while supporting beneficial bacteria. *Allium sativum* stimulates the liver and colon, providing a strong additional effect in the body's detoxification process, improving lymphatic system function, encouraging the body to eliminate waste materials more competently (Rafe, 2014; Shang et al., 2019; Jacob, 2019; Genatrika et al., 2020).

Allium sativum bulbs are rich in phytochemicals (phenolics, flavonoids, alkaloids, terpenoids, and fatty acids), and the antimicrobial activity is attributed to the sulfide compound isolated from freshly ground pulp known as allicin (Cavallito et al., 1944). However, some researchers disagree and believe that allicin itself is very unstable and quickly degrades, arguing that some smaller metabolic breakdown products also have strong antimicrobial effects (Haris et al., 2001).

Various factors (e.g., temperature, pressure, extraction method, solvent type, size, and territorial origin of the plant) influence the quantity and type of bioactive compounds obtained from *Allium sativum* and the content of bioactive compounds correlates with the biological activity of the extracts.

This study aims to assess the antifungal potential of fresh *Allium sativum* extract originating from the Republic of Srpska in comparison with clotrimazole against two isolates of *Candida albicans*, one reference strain of *Candida albicans* WDCM00053, *Saccharomyces cerevisiae* WDCM3058 and *Aspergillus brasiliensis* WDCM00054.

MATERIALS AND METHODS

The *Allium sativum* used in this study was of the domestic variety, matured, and purchased at the city market in Banja Luka. Fresh bulbs were divided into cloves, each clove was peeled and then crushed in a sterile mortar until juice or solution was obtained without any additives (such as water, etc.). The obtained juice was filtered through sterile gauze, and the filtrate (100% aqueous solution of *Allium sativum* extract) was used on the same day in the antifungal testing.

Preparation of disks:

Twenty microliters (20 μL) of *Allium sativum* filtrate were applied to commercial sterile paper disks with a diameter of 9 mm, and 20 μL of clotrimazole solution (10 mg/ml) was used as a positive control. Disks saturated with fresh *Allium sativum* extract (100%) were used as the test group.

Preparation of fungal strains:

The fungal strains used in this study were two isolates of *Candida albicans* from the collection of isolates of the Laboratory for Microbiology of food, feed, and water from PI Veterinary Institute Dr Vaso Butozan, Banja Luka and one reference strain *C. albicans* WDCM 00053, *Saccharomyces cerevisiae* WDCM3058, and *Aspergillus brasiliensis* WDCM 00054. The strains were cultured on Sabouraud dextrose agar for 48-72 hours. They were examined microscopically and subcultured on Sabouraud dextrose broth for 48 hours at 25°C. Broth cultures were kept in the refrigerator until use.

Susceptibility testing to antifungal drugs:

The antifungal activity of fresh *Allium sativum* extract was determined by the disk diffusion method (Kirby-Bauer, 1996). One hundred microliters (100 μL) of each fungal strain from the broth culture was spread on the surface of sterile Petri dishes with Sabouraud dextrose agar using a Drigalski spatula. Disks saturated with fresh garlic juice and clotrimazole disks were placed on agar plates inoculated with the strains and incubated at 25°C for 42-72 hours. After incubation, the diameter of the clear inhibition zone around the disks was measured in millimeters (mm). The test was repeated three times.

Analysis of results:

Microsoft® Excel 2013 was used for the calculations of average values, standard deviations, histograms, and the one-way analysis of variance (ANOVA). ANOVA was used to determine whether there were any statistically significant differences between the similar mean values of inhibition zones.

RESULTS AND DISCUSSION

The tested fungal strains (*Candida albicans*, *Saccharomyces cerevisiae*, and *Aspergillus brasiliensis*) were highly sensitive to *Allium sativum* extract compared to the commercial antifungal drug. The results of the antifungal activity of the tested fungi are shown in Table 1. and the average values of the inhibition zones are presented in Figure 1.

Table 1. The antifungal Activity of *Allium sativum* extract compared to Clotrimazole.

Strain	Inhibition zone (mm ±)	
	***A.sativum* extract**	**Clotrimazole**
Candida albicans 1	40	20
	43	19
	45	19
Candida albicans 2	4	25
	45	24
	42	25
Candida albicans WDCM 00054	45	20
	45	21
	40	19
Saccharomyces cerevisiae WDCM 3058	37	35
	41	31
	45	33
Aspergilus brasiliensis WDCM 00053	7	0
	8	0
	7	0

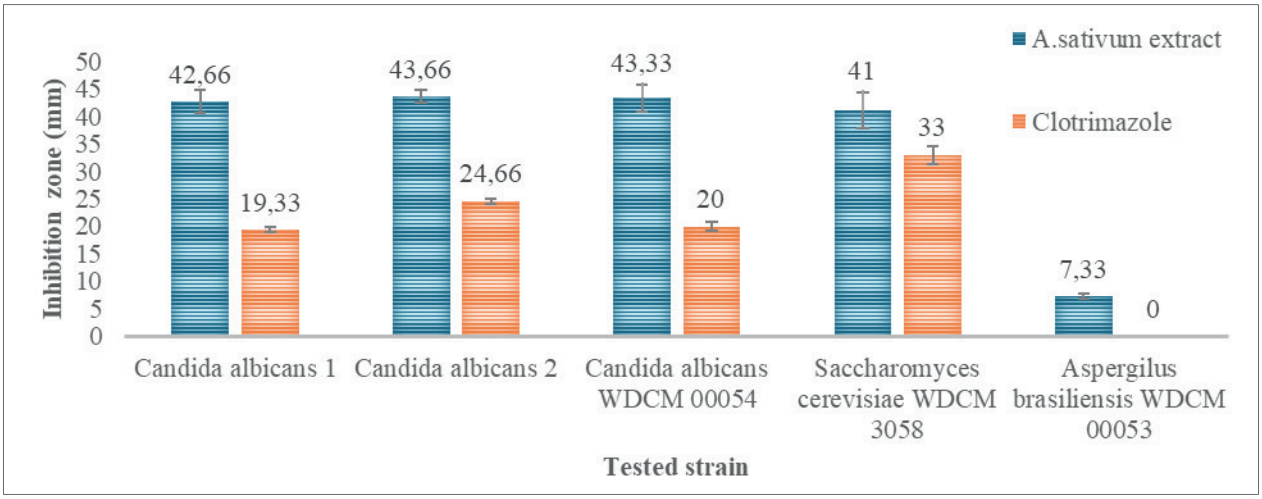

Figure 1. The average values of inhibition zones

The antifungal activity of *Allium sativum* extract, with a prominent mean inhibition zone ranging from 42.66 mm to 43.66 mm, was observed against isolates and the reference strain *Candida albicans*, and 41.00 mm for *Saccharomyces cerevisiae*. The level of statistical significance was set at $p \leq 0.05$ and based on one-way ANOVA there are no differences in the mean value of inhibition zones of yeasts, regardless used strain.

Weaker antifungal activity of *Allium sativum* was shown towards the reference strain *Aspergillus brasiliensis* with a mean inhibition zone of 7.33 mm. The antifungal activity of the commercial antifungal drug for isolates and the reference strain *Candida albicans* ranged from a mean inhibition zone of 19.33 mm to 20.00 mm, and for *Saccharomyces cerevisiae*, it was 33.00 mm. However, it did not affect the reference strain *Aspergillus brasiliensis*, unlike fresh *Allium sativum* extract (mean inhibition zone 7.33 mm). These results have shown that fresh *Allium sativum* extract is more effective than the commercial antifungal drug (clotrimazole) against the tested fungi. Clotrimazole is an antifungal drug commonly used to treat fungal infections, but it is not always effective against all fungi, and it is not always the first choice for treating infections caused by *Aspergillus brasiliensis*.

Many studies investigating the antifungal activity of different concentrations of *Allium sativum* extract indicate that higher concentrations give larger inhibition zones for fungi (Irkin and Korukluoglu, 2007; Agarwal et al., 2010; Kumar et al., 2012; Agustatina & Soekartono, 2021). Additionally, in a study conducted by Agustantina and Soekartono (2021), the effect of different concentrations of *Allium sativum* (5%, 25%, 50%, and 75%) on *Candida albicans* was examined. *Allium sativum* extract exhibited the greatest antifungal effect at the highest concentration (75%) on the tested fungi. In an investigation of the antifungal activity of water and alcohol extracts of six different spices against *Aspergillus niger*, *Candida albicans*, and *Trichophiton rubrum*, Ikegbunam et al. (2016) found that *Allium sativum* extract had the highest antifungal activity against all three tested strains. Ankri and Mirelman (1999) discovered that allicin in its pure form, extracted from fresh bulbs of *Allium sativum*, inhibits the growth of *Aspergillus niger*, *Aspergillus ustus*, and *Penicillium spp*. Allicin isolated from Allium sativum demonstrates potent activity against Candida primarily by inhibiting amino acids and proteins containing thiol, disrupting cell metabolism (Ankri and Mirelman 1999). Human cells contain glutathione, which can bind to allicin, preventing cell damage, while glutathione is lacking in Candida, making allicin a selective and effective candidate in Candida therapy (Davis, 2005).

Cavalcant et al. (2021) emphasize that the extraction method, with particular attention to the solvent used in isolating active substances from *Allium sativum* has impact on the composition and biological

activity of extracts, and his great importance. The use of water for extraction has significant advantages primarily because it is non-toxic to humans and the environment, provides the possibility of clean processing, prevents contamination, and enables the avoidance of extracting unwanted components (Filly et al., 2016; Castro-Puyana et al., 2017; Lefebvre et al., 2021). In addition to water, organic solvents such as acetone, ethyl acetate, hexane, heptane, dichloromethane, methanol, ethanol, tetrahydrofuran, acetonitrile, dimethylformamide, toluene, and dimethyl sulfoxide are used. The use of these solvents achieves a high level of extraction of individual compounds, but the main drawback of these solvents is the health hazards associated with ingestion, inhalation, and skin irritation, as well as possible damage to the central nervous system and other parts of the body (Joshi & Adhikari, 2019). Additionally, a review of the literature has shown that water extracts are best for allicin extraction, while methanol- and ethanol-based extraction methods are best for isolating polyphenols. Water and ethanol extracts have numerous health-beneficial properties (antibacterial, anticancer, antidiabetic, antifungal, anti-hypercholesterolemic, anti-hypertensive, anti-inflammatory, antioxidant, antiparasitic, antiviral, and immunostimulatory effects) and can be used as adjuncts in conventional cancer therapy, but further research in this area is needed. In addition to culinary use, *Allium sativum* extract can be used as an adjunct in conventional therapies for various skin infections and pathologies due to its high concentrations.

CONCLUSION

Fresh extract of *Allium sativum* prepared in a simple manner, without modern extraction methods, was found to be more effective, as revealed by its inhibitory effects with highly significant antifungal efficacy compared to clotrimazole against *Candida albicans*, *Aspergillus brasiliensis*, and *Saccharomyces cerevisiae*.

Based on one-way ANOVA there are no differences in the mean value of inhibition zones of used yeast strains (*Candida albicans* and *Saccharomyces cerevisiae)*.

Since *Allium sativum* is readily available and inexpensive with minimal adverse effects compared to commercial antifungal drugs, further investigations using different concentrations and preparation methods of *Allium sativum* extract are needed to confirm its antifungal efficacy alongside its actual antimicrobial benefits.

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Original scientific paper

Mineralogical and Geochemical Peculiarities of Rare Metal Granite Tillik (Laouni, Central Hoggar, North Africa)

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ABSTRACT: The Pan-African orogeny (800-570 Ma) is thought to have been the last event to affect this vast Hoggar region, while the post-collisional phase of the Pan-African chain (650-570 Ma) continued until (520 Ma) and saw the emplacement of numerous granitic plutons known as "Taourirt" for their potential sources of rare metals. In the central Hoggar, the latest magmatic episodes, represented by albite-topaz (AT) granites, are associated with Sn-Wn mineralization. These granites, which have undergone different degrees of evolution, are currently classified as Rare Metal Granite (RMG). In the Laouni terrane, the Tillik massif outcrops as a small flattened dome, backed by an NNE-SSW-trending accident. It is embedded in highly metamorphosed terrain and regional porphyroid biotite granite. The massif mainly comprises central green granite and leucocratic topaz albite granite, occupying the rest of the dome. Stockscheider pegmatites and greisens mineralized with cassiterite and wolframite occur around the edges of the massif, highlighting the area's significant mineralization potential alongside the granites. Furthermore, the granites are leucocratic and have a mineralogical composition consisting of albite and quartz with snowball structures, which is characteristic of RMG. They are phosphorus-poor, peraluminous, and show relatively flat rare-earth spectra with a strong negative Eu anomaly. The geotectonic sites show that the various samples are projected into the collisional intraplate granite domain, highlighting the transition from the post-orogenic to the anorogenic domain. This study aims to characterize the granites of the Tillik massif petrographically, mineralogically, and geochemically, compare them with the Hoggar rare-metal granites "Ebelekan and Rechla" and with the world-renowned reference granites "Beauvoir and Yichun," and determine whether or not they contain rare metals such as Li, Be, Nb, and Ta.

Keywords: Topaz granites, Columbo-tantalite, RMG, Tillik massif, Laouni, Hoggar, Algeria, Amazonite Granite, Post-Orogenic Granite

INTRODUCTION

The Tillik massif is located approximately 230 km southwest of Tamanrasset, at the southern border of the Tin Begane terrain. This massif of 1.5km x 1km is part of a set of post-orogenic granitic intrusions forming small-aligned domes along a regional NE-SW fault (Fig. 1).

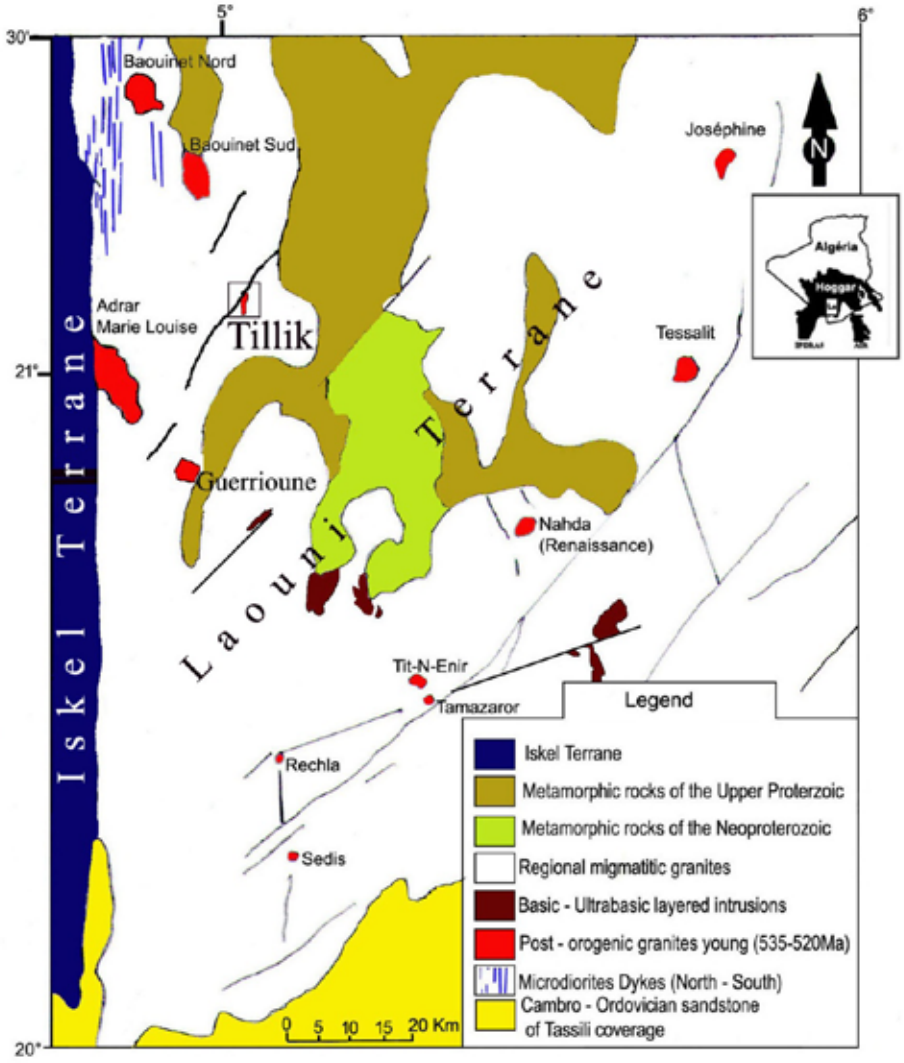


Fig.1. **Location** of the study area.

The Geological and Mining Research Office[1] (BRGM) discovered the Tillik massif in 1959-1960 during a geological mapping trip, in which several minerals have been identified such us Topaz, beryl, Fluorite, and wolframite. The National association of Research and Mining Exploitation SONAREM[2] (1969-1971, 1974) performed systematic geological prospecting and established consequently, a 1:20,000-scale geological map, emphasizing its potential for rare metals.

This study aims to emphasize the unique features of the Tillik granite formation, including its mineral composition and petrographic traits, and explore the geochemical characteristics of the primary, trace, and Rare Earth Elements (REE) present in this formation to determine its typology and compare it to other known examples of Rare Metal Granites (RMG). Moreover, this study aims to provide insight into the geotectonic context of the Tillik granite massif.

MATERIALS AND METHODS

To investigate the mineral phases that constitute the Tillik massif, samples were taken from uncovered polished thin sections, i.e., around twenty (20) thin sections representative of the different facies of the massif studied, prepared at the National Office for Geological and Mining Research (ORGM[3]) in

[1] Bureau de Recherche Géologique et Minière
[2] La Société Nationale de Recherches et d'Exploitation Minières
[3] Office National de la Recherches Géologiques et Minières

Boumerdès. Rock powders, including ten (10) sample powders produced at the Faculty of Earth Sciences, Geography and Territorial Planning Laboratory, University Of Science and Technology Houari Boumediene (USTHB) Algiers.

The following analytical techniques were used; the Transmitted Light Optical Microscope (TLOM) for the study of thin sections, Scanning Electron Microscope (SEM) to identify mineral inclusions that cannot be identified by polarized microscopy, and Electron Microprobe Analyses (EMPA). EMPA were performed using the SX 100 CAMECA (analytical conditions 15Kv, 12nA, and counting time 15s). SEM image by S-4800, signal name: YAGBSE, accelerating voltage: 20Kv, emission current: 9.8Na and counting time 20 to 40s. The observations were performed at the Geo-Ressources Laboratory, Department of Geology, Nancy University (France). Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) and Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) methods were used for primary, trace, and rare earth element analyses conducted at Centre de Recherches Pétrographiques et Géochimiques (CRPG) in Nancy (France).

RESULTS AND DISCUSSION

Post-Orogenic Granites

The Hoggar is characterized by the "Taourirt" event closing the Pan-African orogeny stages. Different granitic plutons were emplaced with varying petrographic, geochemical, and age characteristics from 539-523Ma (Azzouni-Sekkal et al., 2003). They are distributed over three distinct provinces: **Silet** (Iskel terrane), **Tamanrasset**, and **Laouni** (Laouni terrane) (Azzouni-Sekkal, 1989; Azzouni-Sekkal et al., 2003; Boissonnas, 1973). In the Iskel terrane, four main groups have been defined (Azzouni-Sekkal & Boissonnas, 1993), namely:

- **group GI:** Biotite amphibole monzogranite is moderately fractionated, shows weak negative anomalies in Europium (Eu), and is lightly enriched in light Rare Earth Element (REE).
- **group GIIa:** Biotite amphibole monzogranite and syenogranite are less fractionated models with pronounced negative anomalies in Eu.
- **group GIIb:** The Taourirt suite has two highly evolved types - alkali feldspar granites and alaskites. The latter contain pure albite and lithium micas, similar to the Pan-African Tuareg (PAT) found in Tamanrasset.
- **group GIII:** The hypersolvus syenites and granites are little evolved

A hyperaluminous magmatic episode of crustal origin (PAT) in the Laouni terrane of the Tamanrasset region occurred between 539 and 525 Ma (Cheilletz et al., 1992). The latter was succeeded by late magmatism, represented by more evolved albite-topaz granites (**AT**), associated with SN-WN mineralizations (Chalal & Marignac, 1997; Cheilletz et al., 1992; Moulahoum, 1988).

These latest magmatic manifestations (**AT**) have changed to varying degrees and are currently classified as Rare Metal Granites (RMG). For instance, the Ebelekan massif (Low P, High T) is believed to be a representative example of this classification for the entire Hoggar region (Kesraoui, 2005; Kesraoui & Nedjari, 2002; Nedjari et al., 2001). These granites also show great similarities with the so-called evolved RMG known worldwide; France: (Cuney et al., 1992; Raimbault et al., 1995), Yichun; China : (Huang et al., 2002; Lin Yin et al., 1995), Pleasant Ridge ; Canada : (Taylor, 1992), and the SE desert of Egypt: (Kamar, 2015; Masoud & Shahin, 2015; Mohamed, 2012).

In the Laouni region, occurs numerous small post-orogenic granitic domes namely Guerrioune, Tit Enir, Nahda, Sédis, Tamazaror, Tessalit, Rechla (510±15 Ma, dating due to a pegmatite vein, (Gravelle,

1972) as well as the studied Tillik massif. These granitic domes are often associated with wolfram, tin, beryllium, niobium, tantalum, and rare metal mineralizations.

Rare Metal Granites (Rmg)

Rare Metal Granites (RMG) are highly sought-after for their potential to contain rare metals such as Ta, Nb, W, Sn, Li, Be, Rb, Cs, U, and Zr. They are generally characterized by the most fractionated, latest, and apical terms and are emplaced in the late Archean to an-orogenic environments from the Late Archean to the Tertiary. They can take various forms, such as isolated granitic stocks (Beauvoir, France), small granitic domes (Laouni, Algeria), microgranitic veins or quartz-keratophyres (Mongolian ongonites), rhyolites (Richemont, France), volcanic tuffs (Spor Mountain, USA). The latter contains the world's largest reserves of beryllium (bertrandite). Granites containing rare metals can be classified into three different categories:

a. **Peralkaline RMG with [Al/(Na+k) <1]**
   It has low P, high rare REE, and a low Ta/Nb ratio. These granites are weakly enriched in Li, hence the reduced presence of lithium micas.
   These granites correspond to two types: the sodic amphibole-albite granites of the agpaitic class of (Kovalenko, 1977) and the highly fractionated granites of type A1.
b. **Phosphorus-rich peraluminous RMG with [Al/(Na+k)> 1.15]:**
   Phosphorus is present in apatite, amblygonite, montebrasite minerals, and feldspars. Low REE, Th, Y, Hf, Sc, and Pb levels characterize these RMG. Its Ta/Nb ratio is ≥ 1.
   Leucogranitic plutons containing muscovite-biotite are associated with this type of RMG found in post-orogenic continental collision chains.
c. **Phosphorus-poor peraluminous RMG with [1<Al/(Na+k)< 1.15]:**
   Compared to the two previous groups, they have intermediate REE, Th, Y, Zr, Hf, and Th contents. Their REE spectra are typically flat, with prominent negative anomalies in Eu. This type of RMG is found in post-orogenic geotectonic environments.

Geological setting

The Laouni terrane (Fig.1), is an integral part of the LATEA [Laouni, Azroun' fad, Tefedest, Egéré - Aleksod and Aouilène,] metacraton (Liégeois, 2019), which is characterized by a stack of NW-SE trending nappes and abundant Pan-African anatexis granitoids associated with poly structured gneissic formations of the Paleoproterozoic basement, with more or less abundant amphibolite and granulite facies dated at 2000 Ma (Peucat et al., 2003).

In this area, a tectonic unconformity separates two distinct Paleoproterozoic metamorphic ensembles (Bertrand, 1974):

- A lower gneissic unit (**Arechchoum series**) dominated by orthogneisses, leptinites, and quartzo-feldspathic gneisses, associated with rare metasediments in the amphibolite to granulite facies.
- An upper gneissic unit (**Aleksod or Egeré series**) consisting mainly of paragneisses and amphibolite-facies metasediments (quartzites, marbles, and amphibolites).
- Relics of small Pan-African basins, unconformably with the upper gneissic unit, are formed by greenschist-facies referred to volcano-sedimentary formations.

These complexes are intruded by three granite groups: pre- to syn-tectonic anatexic granites of the "Anfeg" type (615 Ma), late-tectonic granites of the Tiferkit type (580 Ma), and the Laouni granites, including the Tillik massif, were emplaced at the end of the Pan-African orogeny. Mafic and ultra-mafic intrusions of mantle origin were emplaced during the post-collisional period (Cottin et al., 1998).

Petrography

The Tillik massif is mainly composed of central greenish amazonite granite, a small spike of leucogranite porphyritic microgranite in the NNE part, and leucogranite-topaz albite granite occupying the rest of the dome. Moreover, the boundaries between these granites are not well-defined.

Stockscheider-type pegmatites surround the massif's northeastern part, accompanying the granites. Mineralized greisens and a quartz vein network are found in the northwest and southeast parts of the massif (Fig. 1 and 2).

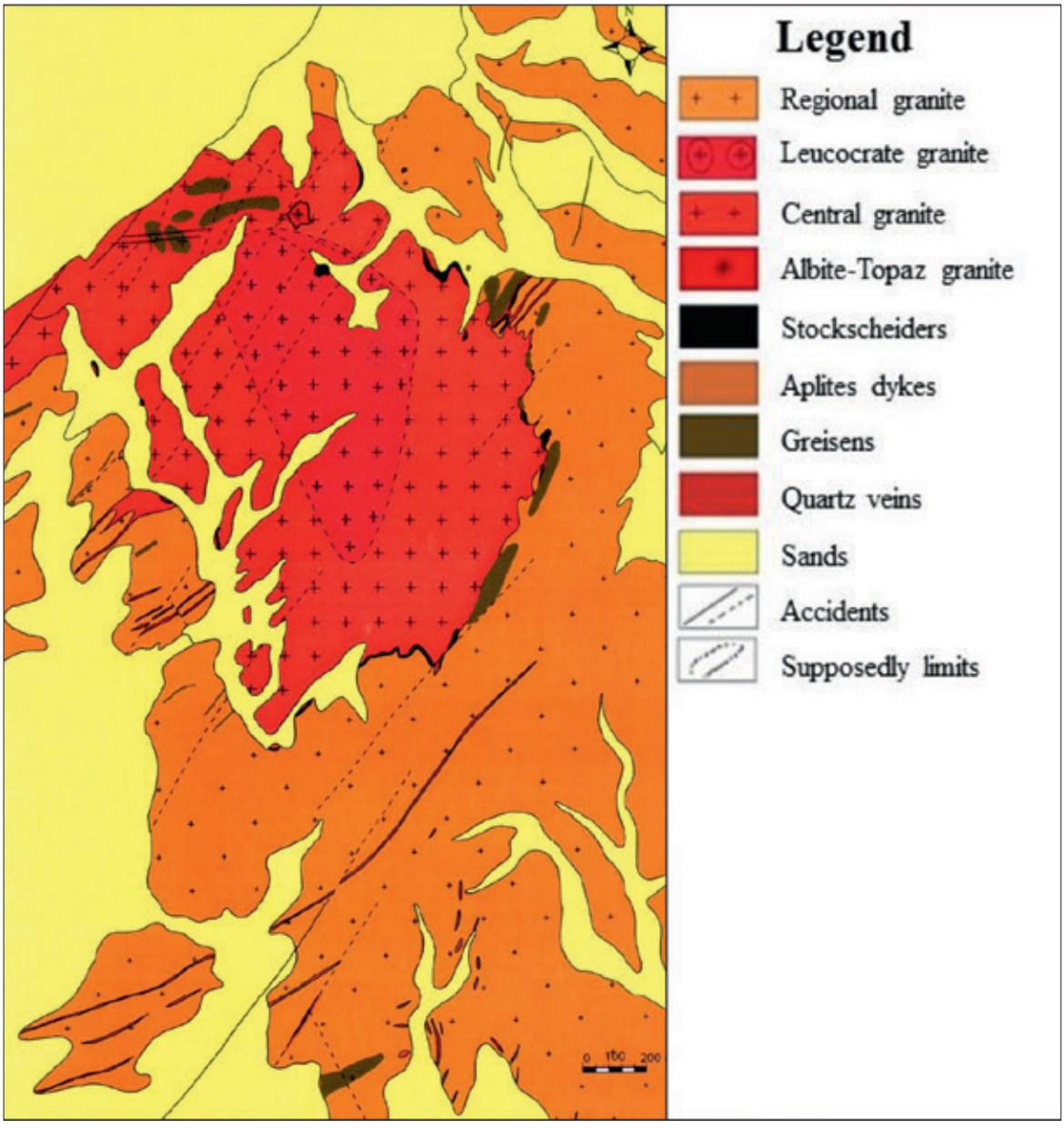


Fig. 2. Geological map of the Tillik area made from a drawing assembly (modified from (SONAREM, 1974)).

Central amazonite granite

It is characterized by a green color mainly due to the abundance of the microcline variety of amazonite. It is medium-grained, equigranular granite primarily consisting of a high-potassium feldspar matrix. In this matrix, well-developed globular quartz and black micas (zinnwaldite) are regularly scattered throughout the rock (Fig. 3b).

The microscopic analysis shows that the central granite has a grainy texture and consists mainly of quartz, with microcline more abundant than orthoclase, weakly pleochroic mica (zinnwaldite) with cassiterite inclusions, and albite. The latter has three generations:

- A first, early generation found in small laths in orthoclase, mica, and quartz. In the latter, albite displays a "snowball" texture characteristic of advanced rare-metal granites.
- A second generation of interstitials in automorphous laths with characteristic polysynthetic macles.
- A third generation in small-budding crystallites in microcline. This last generation of albite would be replaced by microcline and amazonite varieties.

The same phenomenon is observed in the amazonite leucogranites of Xinjiang in NW China (Gu et al., 2011).

The microcline, amazonite variety would replace this last generation of albite. This same phenomenon is observed in the amazonite leucogranites of Xinjiang in NW China (Gu et al., 2011). Topaz and Fluorite are rare.

Microscopically, the amazonite variety displays the same characteristics as microcline, except for the presence of Rb and Cs impurities in the crystal lattices. Microprobe analysis of a microcline yielded 0.02% Cs and 0.09% Rb.

The opaque minerals represent accessory minerals. They come in various forms, most often in the form of small, rounded, or scattered rods. Furthermore, some produce pleochroic halos. They are located in micas, following or crossing cleavage planes. They can also be found in quartz, feldspar, and topaz. These opaque minerals have been studied mineralogically by scanning electron microscope and microprobe (Hamis et al., 2021).

Albite - topaz granite

This highly leucocratic granite shares the same features as the preceding one. However, it appears to be whiter due to a decrease in microcline and an increase in albite and quartz. This granite also contains a relatively large amount of topaz (Fig.3c).

Under the microscope, the granite displays the same features as the central granite. However, we have observed certain peculiarities in the area. Firstly, the grain size appears to be finer than the surrounding area. Secondly, there is a significant decrease in potassic feldspar while the proportion of albite has increased. The topazes are also more extensive and abundant, as shown in (Fig. 3e). However, the proportions of micas remain the same. The characteristic "snowball" structure can be seen in (Fig. 3f).

Porphyritic microgranite

It outcrops as a small point in the northeastern part of the massif. Its spatial relationships with the surrounding topaz albite granite are unclear, but it appears to be intrusive. This light-colored granite (leucocrate) shows phenocrysts of globular quartz and feldspars. It is interspersed with albites and white micas.

Observations under the microscope show that the rock has a porphyritic micrograiny texture. Quartz appears in large, often fissured, automorphous to sub-automorphous patches up to 2mm. It shows magmatic corrosion structures and contains small plagioclase laths with small quartz crystals in inclusion, often forming a "snowball" structure.

Pegmatites

They often outcrop in zones with few centimeters in diameter inside granites. They feature large crystals of quartz, potassium feldspar, topaz, and disseminated micas. All these minerals are embedded in a feldspathic matrix.

Under the microscope, the rock has a pegmatitic texture represented mainly by automorphic to sub-automorphic phenocrysts of quartz and albite. Potassium feldspars (microcline, orthoclase), micas (zinnwaldite and muscovite), and topaz are scarce. Quartz contains embedded albite laths.

Phenocrystalline microcline is often perthitic. When in contact with micas, the latter interpenetrate along the cleavage planes of potassium feldspar. They also contain albite laths and fine quartz crystals. Oxides underline cracks. Orthoclase often occurs in smaller patches and contains albite laths and small xenomorphic quartz crystals.

Weakly pleochroic zinnwaldite, often in large patches, comprises inclusions of oxides, muscovite, and albite crystallites.

The stockscheiders

Stockscheider-type pegmatite comprises mega-crystals of potassic feldspars, mostly feathery with disseminated micas. The whole is immersed in a matrix of potassium feldspars and quartz (Fig. 3d).

Under the microscope, sub-automorphic phenocrysts of perthitic orthoses, which took their time to crystallize first, can be seen. They contain quartz, micas, and albite in fine laths. The medium-sized equigranular quartz occupies the cavities between the potassium feldspar phenocrysts. They often show signs of magmatic corrosion. Inclusions include Fluorite and iron oxides. Micas in small, abundant patches are moderately pleochroic and occupy the voids between quartz crystals. These micas contain needle-like rutile, which are often invaded by oxides, and are sometimes fully substituted.

Topaz is relatively abundant and fills the interstices. It occurs in sub-automorphic patches up to 02mm in size. It also contains fine mica crystals.

The greisens

They are found in the northwestern and south-eastern parts of the massif (Fig. 2). They occur as lenticular bodies and rarely as veins. The stone is dark gray. The mineralogical composition is quartz, black micas, and oxides (Fig. 3a).

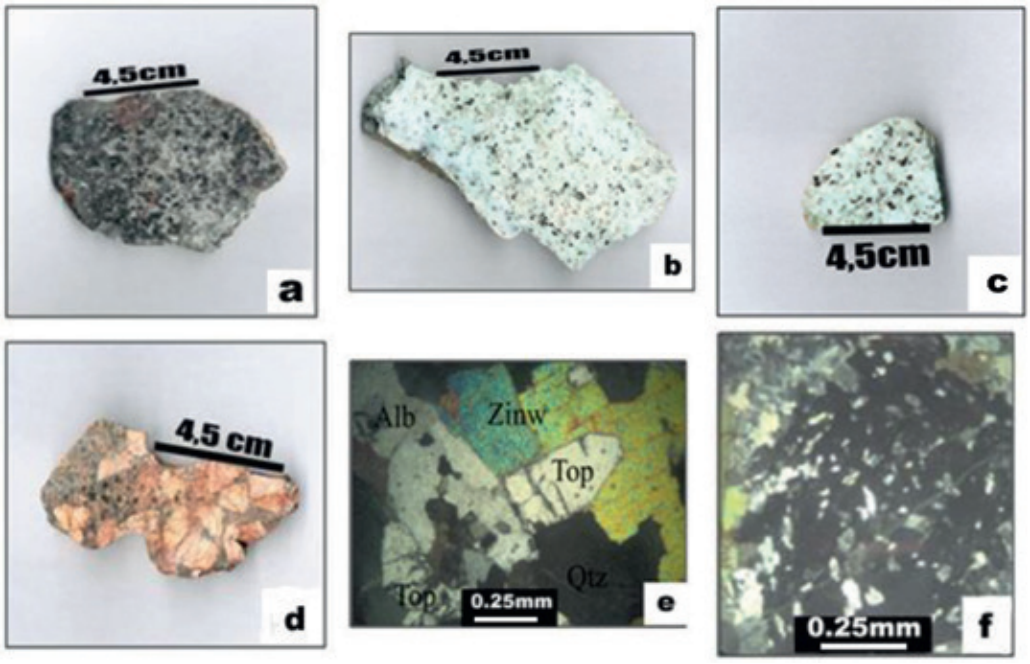


Fig. 3. Granite greenish central microcline, Greisens (a) amazonite variety (b), Granite albite topaz (c), Stockscheider "pegmatite feather" (d), Granite albite topaz microscopy (e), snowball structure of albite topaz granite (f).

Mineralogy

The micas in Tillik granites are weakly pleochroic, occurring in irregular patches and rarely in automorphic sections. Micas are also found in cracks and inclusions. They contain numerous inclusions (albite, quartz, Fluorite, zircon, columbo-tantalite, monazite and topaz).

Observations with a scanning electron microscope show a muscovite-cored zinnwaldite (Fig. 7d).

The micas in the topaz albite granite show relatively high Rb, Li, and F contents (Table 1) and project into the zinnwaldite field. Greisens extend into the siderophyllite field: $K2^{XII}(Fe^{2+}{}_4Al_2)^{VI}(Si_4Al_4)^{IV}O_{20}(OH)_4$, (Fig. 4 a and b).

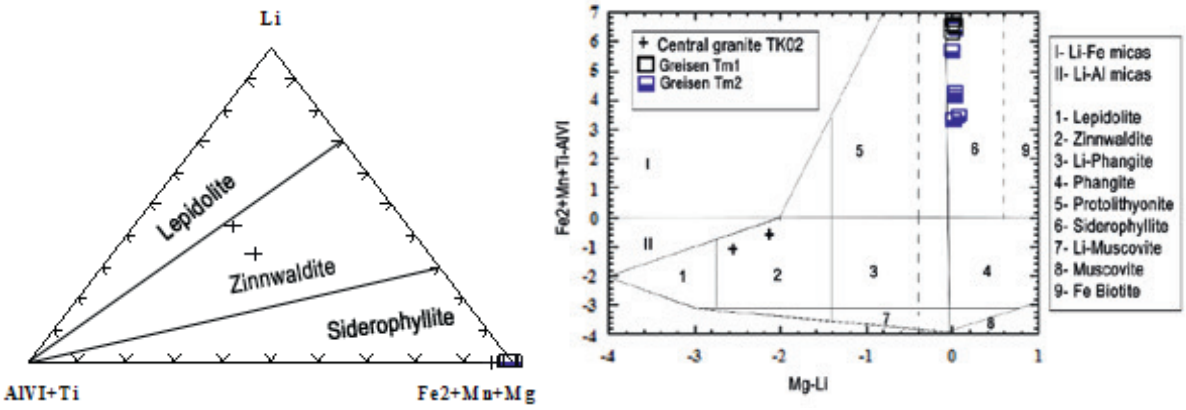


Fig.4. Distribution mica granite and greisen of the Tillik massif in the diagram (Tischendorf et al., 1997) a) Li-Al+Ti-Fe+Mg+Mn (Stone et al., 1988) ; and b) (Mg-Li) – (Fe+Mn+Ti-AlVI) (Tischendorf et al., 1997).

Topaz

Relatively abundant in these facies, it often occurs in large automorphic to sub-automorphic patches up to 5mm in size (Fig. 3e).

Topaz has substantial relief and is criss-crossed by numerous fractures underlined by oxides. When these fractures are open, they are filled with micas, quartz, and albite.

Inclusions include albite crystallites, fine columbo-tantalite rods, and fine quartz crystals. Topaz grades in topaz granite are higher in fluorine (F: 21.45) and lower in silica (SiO_2: 31.36), while the opposite is true in the case of greisens. They are lower in fluorine (F: 13.08) and higher in silica (SiO_2: 33.04) (Table 1).

Table 1. Topaz analysis of the Tillik massif (*TK02: Central granite; TM1 and TM2: Greisen*)

Sample	TK02-A	TM1	TM2	TM2	TM2
Analysis %	41	35	19	21	24
SiO_2	31.368	33.392	33.381	32.449	33.041
Al_2O_3	56.408	56.751	57.263	57.516	57.047
F	21.457	14.151	13.081	14.149	13.226
O=F	-9.01	-5.94	-5.49	-5.94	-5.55
Total	100.22	98.35	98.23	98.17	97.76
base O_2	5	5	5	5	5
Si	0.965	0.999	0.993	0.974	0.990
Al	2.046	2.001	2.009	2.035	2.014
F	2.088	1.339	1.231	1.343	1.253
OH	-0.088	0.661	0.769	0.657	0.747
F/F+OH	1.044	0.669	0.616	0.672	0.626
Total O_2	2.704	2.781	2.796	2.772	2.778
Structural Formula of topaz : $Al_2SiO_4(OH,F)_2$					

Accessories

Columbo-tantalites

Nb and Ta are accessory minerals disseminated in granites, greisens, and pegmatites. They occur mainly as inclusions in micas. Columbo-tantalites are characteristically rod-shaped and rarely prismatic. They vary in size from 20 µm to 120 µm, occasionally with fractures, and contain zircon inclusions.

Under the scanning electron microscope, they display a relatively well-expressed zonation of shade, with the core of the crystals darker than the edges, which is due to the heterogeneity of their chemical composition underlined by the substitution between the pairs of significant elements: Nb → Ta and Fe → Mn.

Such zones, whose contours are more or less regular, are represented by a dark core (enriched in Nb) evolving towards a light periphery (enriched in Ta) (Fig. 5).

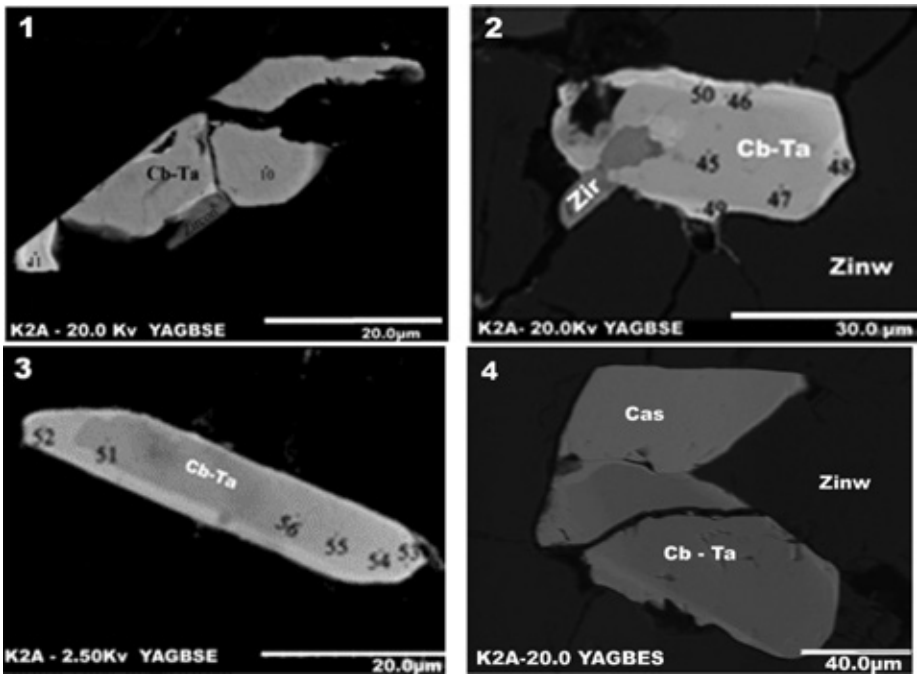


Fig. 5. Some forms of Columbite-tantalites of the Tillik massif analyzed by SEM. Abbreviation: *(Cb-Ta: Columbo-tantalite, Zir: Zircon, Zinw: Zinnwaldite, Cas: Cassiterite)*

On the chemical aspect

Central granite columbo-tantalites are richer in niobium than tantalum. They have high titanium contents and are slightly more manganiferous than ferriferous (Table 2). Columbo-tantalite is zoned with a ferro-columbite core enriched in Mn and a manganocolumbite edge, demonstrating an evolutionary trend towards manganotantalite. The transition from the core to the rim is marked by an apparent hiatus in the increase in Mn/Mn+Fe and Ta/Ta+Nb ratios (Fig. 6).

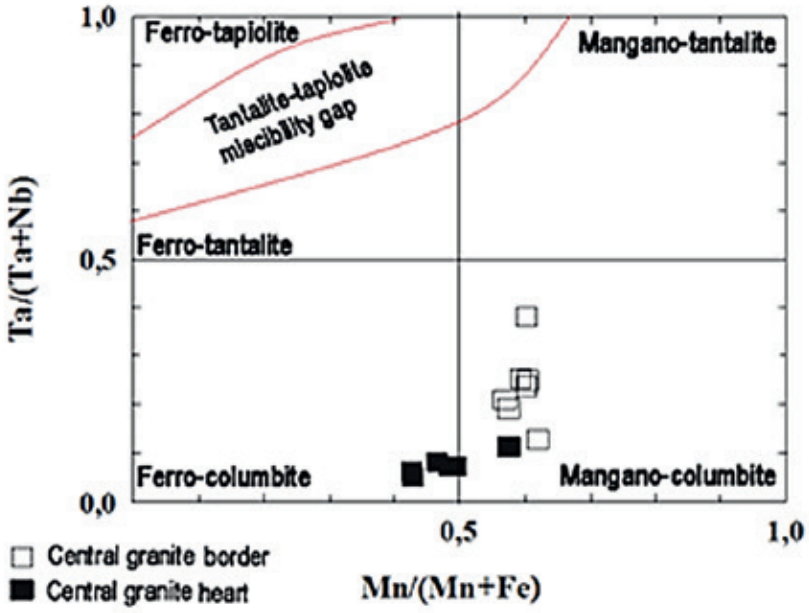


Fig. 6. Columbite-tantalite compositions of the central ferro-columbite granite, at the limit of manganese-columbite.

Table 2. Analysis of columbite-tantalites From the Tillik massif

DataSet/ Point	TK02-A1/10	TK02-A2/45	TK02-A2/47	TK02-A3/51	TK02-A3/54	TK02-A3/55	TK02-A3/56	TK02-A1/11	TK02-A2/46	TK02-A2/48	TK02-A2/49	TK02-A2/50	TK02-A3/52	TK02-A3/53
	Heart (gray area)							**Border (light area)**						
TiO_2	1.22	1.19	1.01	1.09	0.89	0.95	1.02	1.55	1.46	1.28	1.77	2.04	1.33	1.22
MnO	8.73	8.74	9.38	10.03	11.96	11.32	9.02	11.50	10.69	11.36	11.62	10.55	10.82	11.47
FeO	11.69	11.93	11.01	10.54	7.55	8.54	9.66	8.01	7.92	7.54	7.57	6.99	8.16	7.24
Sc_2O_3	0.24	0.27	0.19	0.27	0.22	0.22	0.23	0.40	0.34	0.40	0.48	0.59	0.37	0.34
Nb_2O_5	**68.52**	**67.33**	**66.75**	**66.37**	**62.07**	**63.70**	**64.27**	**49.73**	**55.19**	**51.69**	**49.06**	**37.67**	**53.93**	**55.63**
SnO	0.19	0.16	0.27	0.05	0	0.12	0.16	0.29	0.06	0	0.21	0.08	0.06	0.14
Ta_2O_5	**6.34**	**7.50**	**9.11**	**8.85**	**15.09**	**13.25**	**8.35**	**27.86**	**21.42**	**26.97**	**26.56**	**38.50**	**23.58**	**20.82**
WO_3	1.25	1.07	0.75	1.30	0.08	0.38	1.11	0.05	0.45	0	0	0	0.21	0
UO_2	0.13	0	0.23	0	0	0	0	0	0.12	0	0	0.08	0.132	0
Total	98.34	98.21	98.74	98.54	97.9	98	93.85	99.43	97.71	99.26	97.29	96.52	98.61	96.88
Moy. Nb				65.57							50.41			
Moy. Ta				9.78							26.53			

Monazite

Monazite is found in albite-topaz granite. It is automorphic, with well-defined outlines 150µm in size. It occurs as an inclusion in quartz and zinnwaldite, forming a pleochroic aureole, and in cracks in Fluorite.

Under the scanning electron microscope, monazite shows a remarkable dominance of cerium (Fig. 7c).

Cerianite

Cerianite is a cerium oxide of the general formula (Ce, Th) O_2, with other REE. The chemical composition of cerianite shows that CeO_2 can exceed 80% and ThO_2 5-6%. It also contains other REEs and traces of Nb and Ta.

The SEM-observed cerianite occurs in albite-topaz granite, as an inclusion in micas. It adjoins a columbo-tantalite rod (Fig. 7b) characterized by automorphic shape with corroded contours. Its size can reach 130µm.

An elemental map of the cerianite crystal was produced using Scanning Electron Microscopy (SEM). The crystal displays an even distribution of Ce, Pr, and Nd throughout. However, Th is mainly concentrated at the periphery, while La is primarily present at the core of the mineral. A buffer zone exists between cerianite and columbo-tantalite, enriched in P and likely monazite. The columbo-tantalite does not contain any of the analyzed elements, i.e., rare earths and P.

Fluocerite and melanocerite

These minerals were determined by SEM, and appear as inclusions in Fluorite. Fluocerite and melanocerite contain high levels of the radioactive elements of cesium and thorium. Melanocerite is a mineral with a low fluorine content (1.41) and very little La_2O_3 (0.00), but it is rich in P_2O_5 (5.22) and Ce_2O_3. On the other hand, fluocerite has a high concentration of fluorine (42.98) and low levels of alumina, phosphorus, and potassium.

Other minerals

Zircons are very abundant in the various facies of the Tillik massif. They are found in thin sections of quartz and, more often, in micas, where they develop pleochroic aureoles. Observations with SEM show that are present in several minerals such as micas, quartz, albite, topaz, Fluorite, and columbo-tantalite. The zircons have not been analyzed.

Apatite is a rare mineral observed under a polarizing microscope as fine automorphic rods in micas. Under the SEM view, apatite fills cracks in mica and zircon or as isolated crystals (Fig. 7c).

Conversely, Fluorite is often sub-automorphic and small, typically ranging from 30µm to 40µm. SEM analysis reveals that Fluorite includes very small albite laths and numerous zircons (Fig. 7a).

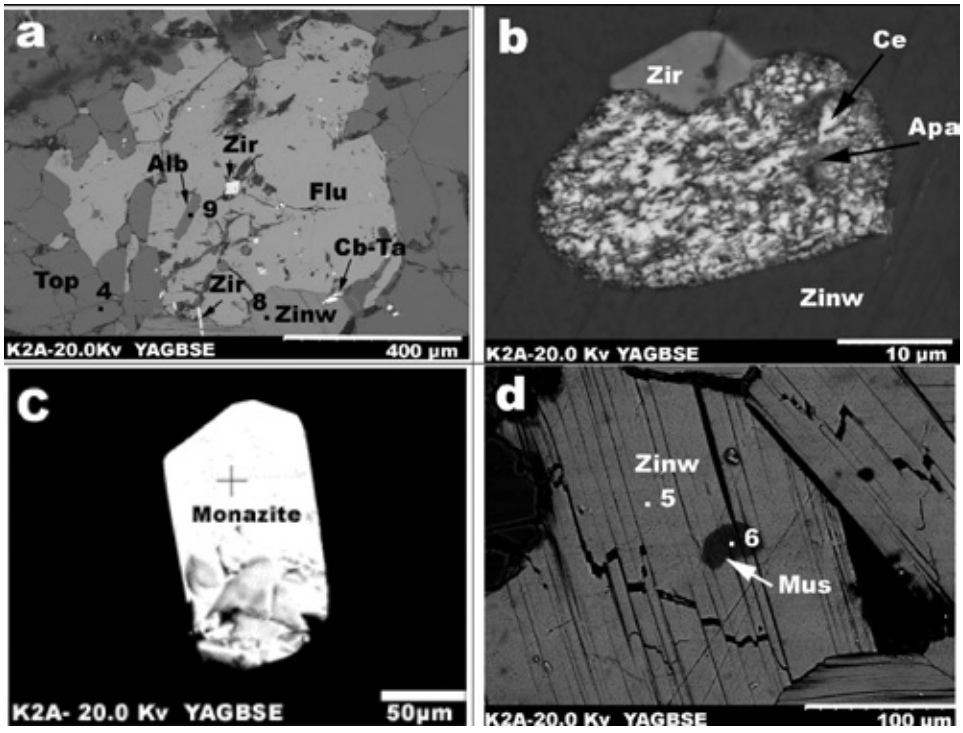


Fig. 7. Fluorite (Flu), Zinnwaldite (Zinw) and topaz (Top) association (a), Cerianite (Ce) and apatite (Ap) in zinnwaldite(b), Monazite (c) and Zinnwaldite with muscovite (Mu) core (d) using the SEM

Geochemistry

The petrographic and mineralogical analysis is reinforced by geochemical data to determine the location of the studied granites compared to the known rare-metal granites in the region, including major elements, REE, and trace elements.

Major elements

The Tillik massif granites are highly siliceous (73.41< SiO_2 <75.29), alkaline-rich (9.04< Na_2O + K_2O <12.59) and peraluminous (14.58 < Al_2O_3 <15.59).

MnO contents can generally be considered relatively high (0.03< MnO <0.10), and these differences are probably due to the abundance of micas and oxides in the various facies. The rocks of the Tillik massif are depleted in iron (0.41 < Fe_2O_3 < 0.54), calcium (0.28 < CaO < 0.06), phosphorus (0.04>P_2O_5>L.D), and titanium (L.D <TiO_2<0.01) (Table 3).

Fluorine was not detected, but lithiniferous micas (zinnwaldite) and topazes had high fluorine contents (2.78 < F < 7.55 and 13.08 < F < 21.45, respectively).

The Harker diagrams reveal a negative correlation between alumina, ferromagnesium, and silica, as opposed to alkalis and calcium, which increase with decreasing silica.

The A/CNK molar ratios of Tillik massif granites are greater than unity (1.5). These values characterize peraluminous granites in Shand's classification (Shand, 1927). This data is also supported by normative corundum values between 1.63 and 2.38. The ANK/ACNK diagram by (maniar & piccoli, 1989) confirms these findings, indicating that the granites analyzed fall within the peraluminous range.

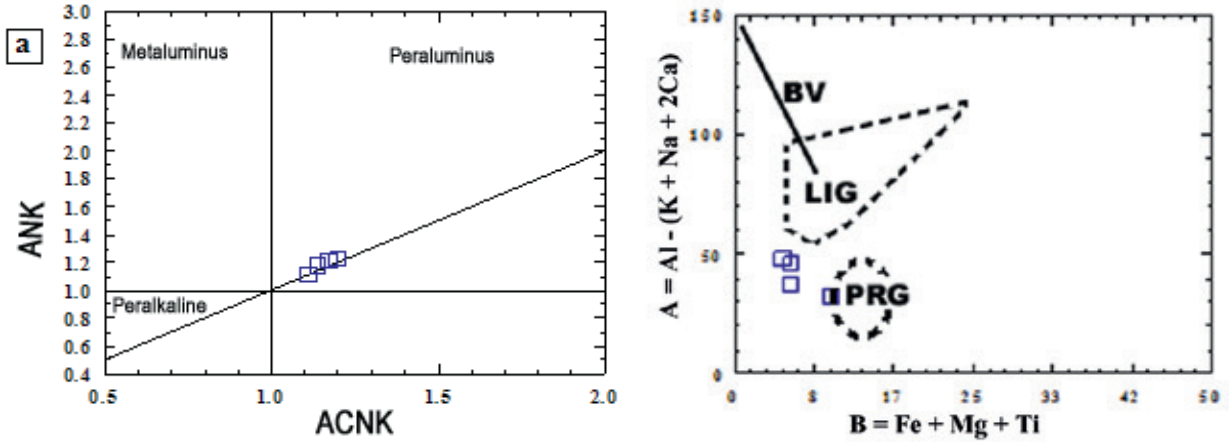


Fig. 8. Al_2O_3/ (Na_2O+K_2O) Tillik vs alumina to lime and alkalis Al_2O_3/Na_2O+K_2O+CaO after (Maniar & Poccoli, 1989), comparison with reference granites; [Bv: Beauvoir and LIG: Erzzebirge (Raimbault et al., 1995), PRG: Pleasant Ridge (Taylor, 1992)] in the A-B of (Debon & Lefort, 1988).

Table 3. Tillik granites majors' elements analysis

Samp.		TK 02	TK 03	TK 12	TK 04		TK02	TK03	TK12	TK04
SiO_2	%	73.41	75.29	73.96	68.17	**A/CNK**	**1.17**	**1.20**	**1.14**	**1.11**
Al_2O_3	%	15.59	14.58	15.45	17.22	**A/NK**	**1.21**	**1.22**	**1.17**	**1.11**
Fe_2O_3	%	0.54	0.41	0.49	0.65	K_2O/Na_2O	0.89	1.34	0.87	2.79
MnO	%	0.08	0.10	0.03	0.04	CaO/Na_2O+K_2O	0.03	0.01	0.02	0.00
MgO	%	< L.D	< L.D	< L.D	0.12					
CaO	%	0.28	0.13	0.23	0.06					
Na_2O	%	4.94	3.86	5.09	3.32					
K_2O	%	4.38	5.18	4.43	9.25					
TiO_2	%	0.01	0.01	< L.D	0.01					
P_2O_5	%	< L.D	0.04	0.02	< L.D					
PF	%	0.85	0.67	0.47	0.71					
Total	%	100.07	100.27	100.16	99.54					

Tk02: Central granite
Tk03: albite-topaz granite with pegmatite pocket
Tk12: Albite-topaz granite
Tk04: Pegmatite in albite-topaz granite

Trace elements

Tillik massif granites are poor in trace elements with large ionic radii (LILE): Ba, Sr, Y, and Zr. However, they are characterized by very high levels of Rb and Ga. Generally, Micas and feldspars control these elements. It is admitted that the "LILE" components behave normally for advanced granites. The levels of rare alkaline elements such as Be and Cs are relatively low and are primarily influenced by micas. However, lithium has not been analyzed (Table 4).

Table 4. Tillik granites trace elements analysis

Samples	Ba	Rb	Sr	Zr	Hf	U	Th	Cs	Ga	Y	Cr
TK 02	10.24	1355	15.64	23.84	3.492	1.436	13.58	9.609	47.39	11.96	113.3
TK 12	18.78	1122	8.815	19.91	3.289	2.701	13.14	4.047	53	3.391	184.1
TK 03	27.77	1509	5.497	21.96	3.937	1.929	7.552	1.498	47.52	4.257	74.14
TK 04	22.56	2290	10.21	4.585	0.847	10.94	4.467	11.32	60.11	0.763	185.3
Samples	**Be**	**Nb**	**Ta**	**W**	**Sn**	**Pb**	**Zn**	**Cu**	**V**	**Bi**	
TK 02	4.589	54.58	17.59	4.762	98.51	50.77	69.47	< L.D	3.229	0.932	
TK 12	3.741	46.93	31.39	9.682	115.7	38.69	28.04	< L.D	5.027	0.262	
TK 03	< L.D	60.83	25.64	5.851	53.27	37.39	122.5	< L.D	2.047	0.164	
TK 04	3.747	15.8	12.51	12.98	86.19	64.51	72.66	10.49	5.682	12.11	
Samples	Ni	Ge	Co	Mo	Nb/Ta	Rb/Sr	K/Ba	K/Rb	Zr/Hf	Th/U	
TK 02	11.2	4.882	0.648	3.431	3.10	86.63	09.08	00.06	06.82	09.45	
TK 12	11.81	4.235	0.711	5.495	01.49	127.28	05.00	00.08	06.05	04.86	
TK 03	8.646	5.444	< L.D	3.115	02.37	274.51	03.96	00.07	05.57	03.91	
TK 04	5.534	5.466	0.622	9.479	01.26	224.28	08.70	00.08	05.41	00.40	

The Ba/Rb ratio, ranging from 0.007 to 0.01, is relatively low and often related to Sn enrichment, a characteristic of highly differentiated, mineralized granites.

The triangular diagram (Rb/Sr/Ba) shows a high concentration of grades in the rubidium pole. It confirms their character as highly differentiated granites comparable to those of Ebélekan, Egele, and Nuweibi (Fig. 8).

Elements with high ionic charges (HFSE)

The element Sn has very high values. Although W occurs as wolframite with cassiterite in the gre-

isens at the top of the dome, it has very low values. Niobium grades are significantly higher than tantalum, and thorium grades are higher than uranium. In addition, the ratios (Nb/Ta) and (Th/U) are well above unity.

The levels of transition elements such as Pb and Zn are very high in the area. High levels of Cr and Ni suggest contamination due to assimilation from the primary and ultrabasic rocks in the region. By normalizing multi-element curves to the averages of the lower continental crust (McLennan, 2001), it is clear that the granites of the Tillik massif have positive anomalies for Rb, Sn, Ta, Nb, La, Y, and Zn. On the other hand, Negative anomalies are most notable for Th, U, Zr, Eu, Ba, and Sr (Fig. 9).

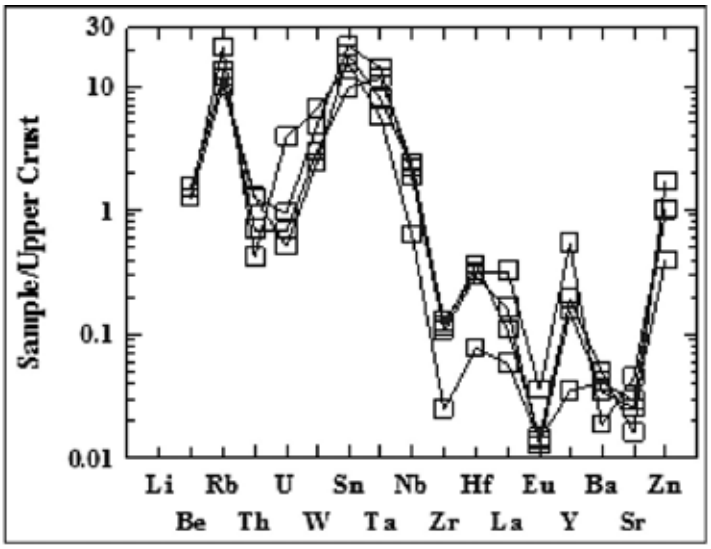


Fig. 9. Curves trace element contents normalized to the upper continental crust for the massive granite Tillik. The composition of the continental crust top is from (McLennan, 2001).

Rare Earths Elements

Accessory minerals like thorite, xenotime, uraninite, monazite, cerianite, and zircon often separate REE. These minerals are commonly found in Tillik granites. The central granite is highly enriched in REE, whereas the albite-topaz granites become increasingly depleted towards the periphery. The periphery region contains many pegmatitic zones with a REE sum ranging from 11.05 to 88.45. Data on REE indicate a decrease in concentration from the center to the edge of the massif (Table 5).

Table 5. Tillik granites rare elements analysis

Samples	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho
TK 02	9.562	34.93	4.04	11.82	4.119	0.031	2.519	0.72	5.192	0.989
TK 12	4.836	16.17	1.957	5.152	1.672	0.011	0.852	0.247	1.762	0.321
TK 03	3.266	9.056	0.779	2.079	0.649	0.013	0.501	0.181	1.682	0.375
TK 04	1.743	5.564	0.447	1.097	0.277	0.012	0.196	0.051	0.397	0.083
Samples	**Er**	**Tm**	**Yb**	**Lu**	**Total**	**Eu/Eu***	**La/Yb_N**	**La/Sm_N**	**Gd/Yb_N**	**$TE_{1,3}$**
TK 02	3.599	0.902	8.745	1.289	88.45	0.03	0.76	1.46	0.24	1.57
TK 12	1.24	0.344	3.501	0.521	38.58	0.03	0.96	1.82	0.20	1.58
TK 03	1.498	0.371	3.644	0.536	24.44	0.07	0.62	3.16	0.11	1.43
TK 04	0.305	0.072	0.704	0.109	11.05	0.16	1.72	3.96	0.23	1.60

Rare-earth spectra (Fig. 10) demonstrate enrichment in the central granite (1), which is 60 times greater than chondrite standards. Moreover, the topaz albite granite (2) shows ten times the norm but is more depleted than the central granite. In contrast, the pegmatites (3) show a rare-earth spectrum below

10, with depletion progressing from the core to the periphery. This phenomenon can be explained by the leaching of rare earths by hydrothermal solutions towards the eroded summit parts of the massif. Rare earth spectra are relatively flat, with a pronounced Eu anomaly (0.03<Eu/Eu*<0.16).

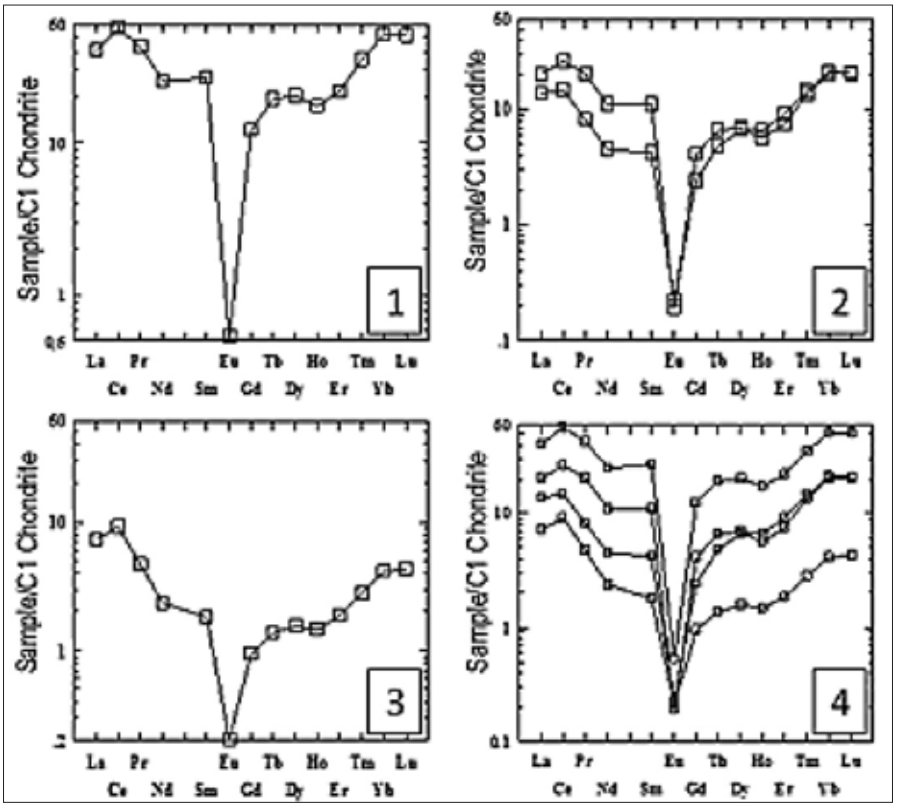


Fig. 10. Spectra of Rare Earth: central granite (1) topaz-albite granite (2) pegmatite (3) granites Tillik (4).

Geotectonic Site

The Tillik massif granites are projected into the domain of strongly fractionated alkaline granites (Fig. 13). According to (Pearce et al., 1984), geotectonic diagrams can be used to identify the location of various samples. In this case, the samples fall within the category of collisional intraplate granites (Fig.12 a,b). Additionally, the transition from the post-orogenic to the anorogenic domain can be highlighted using the R1-R2 diagram (Fig. 11).

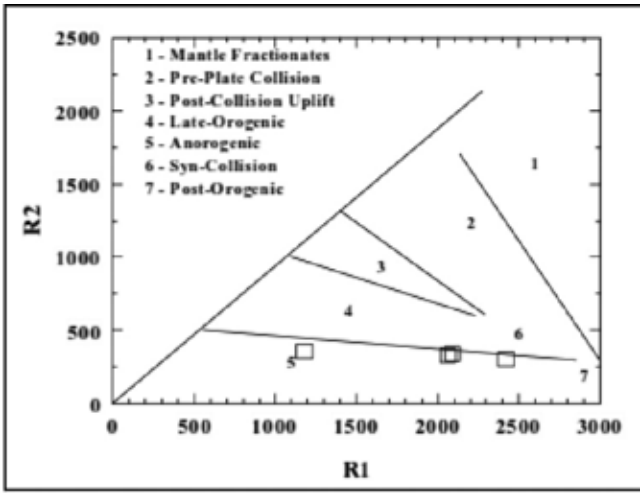


Fig. 11. Tillik granites mapped on the R1-R2 diagram (De la Roche et al., 1980). Fields shown are from (Batchelor & Bowden, 1985).

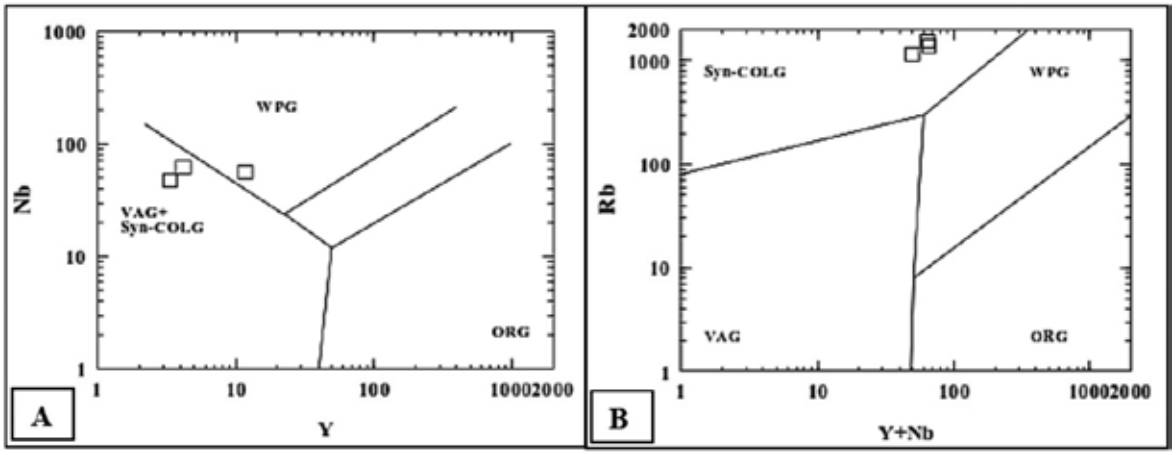


Fig. 12. Geotectonic mapping of the granites investigated in the (Rb vs Y+Nb in (a) and (Rb vs Y) diagrams by (Pearce, 1996) in (b). (COLG: Collision Granite; ORG: Ocean Ridgee Granite; VAG: Volcanic Arc Granite; WPG: Within Plate Granite)

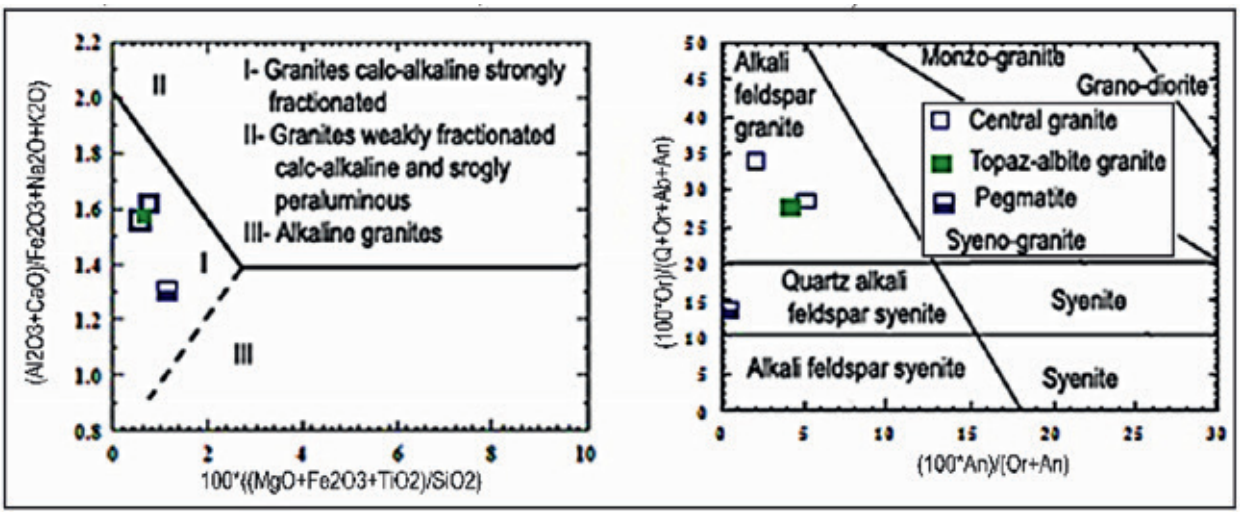


Fig. 13. Tillik granites are projected in the field of calc-alkaline granites strongly fractionated according to diagram of Sylvester (Sylvester, 1989).

Standard data (Diagram: Quartz- Albite- Orthose)

In the Q-Ab-Or diagram (Fig. 14), the representative points of the Tillik massif granites project between the 1- and 2% fluorine minimums at moderate water vapor pressure (3-5 kb). This suggests that they were formed at moderate levels in the crust. Furthermore, the pegmatite sample tends to approach the orthoclase pole.

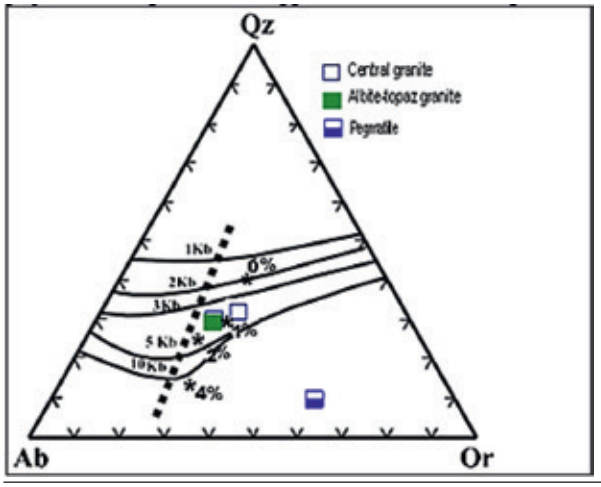


Fig. 14. Qz-Ab-Or ternary diagram; the dashed line represents the minimum melting points in the granite system at different water-vapor pressure; 1, 2, and 3 kb, after (Luth et al., 1964; Tuttle & Bowen, 1958); 5 and 10 kb, after (Luth et al., 1964); and 0,1,2,4% of fluor (Manning & Holthuis, 1981)

Comparison of Tillik granites with reference granites

Tillik granites show a regular evolution in the A-B diagram of (Debon & Lefort, 1988) (Fig. 15). They are more peraluminous and less ferromagnesian, although positioned in the same field as the Ebelekane and Tamanrasset granites, which show the opposite trend (Kesraoui & Nedjari, 2002).

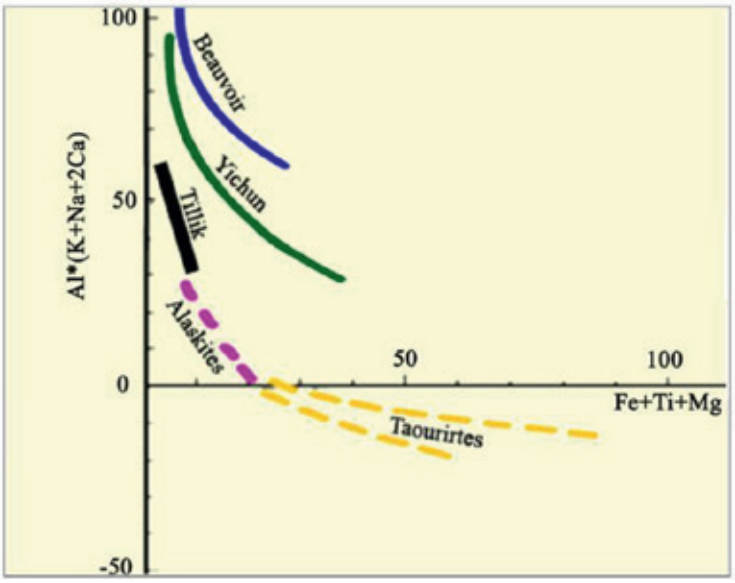
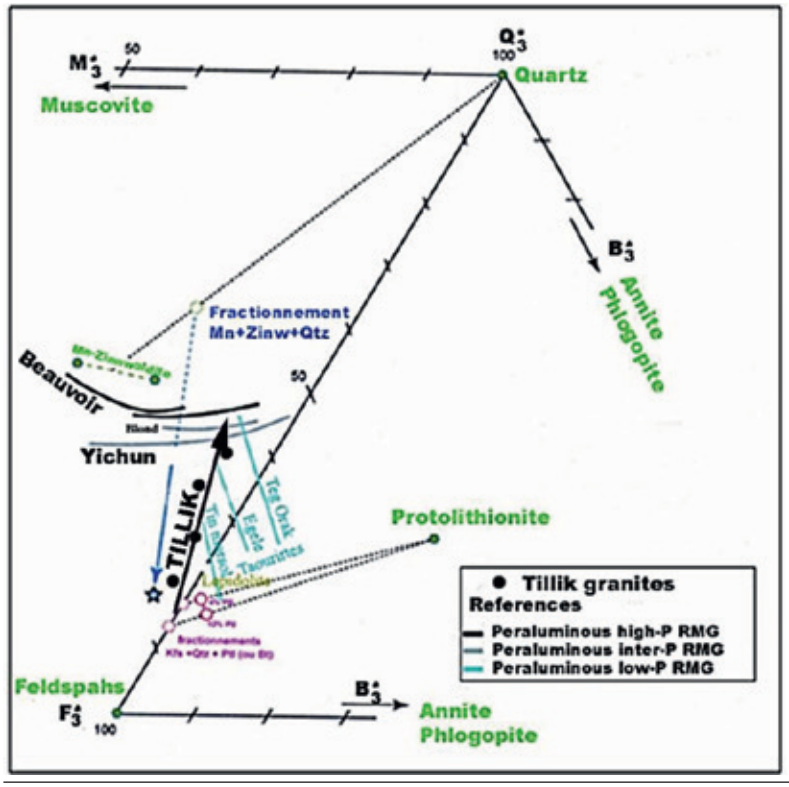


Fig. 15. Position of the Tillik granites in the A-B diagram by (Debon & Lefort, 1988). Alaskites and Taourirts (Azzouni-Sekkal, 1989), for comparison: (Beauvoir ; France: (Cuney et al., 1992; Raimbault et al., 1995), Yichun ; China :(Lin Yin et al., 1995)).

Overall, the granites of the central Hoggar occupy an intermediate position between the alaskites, "the most evolved granites of the Iskel terrane, Taourirt," and the most evolved and peraluminous Beauvoir granite. This fan-shaped arrangement suggests a mixture of two magmatic strains (Bouabsa et al., 2005). One of these would be peraluminous of the "primitive" Beauvoir type, while the other would match the more fractionated terms of the Iskel terrane. The absence of "Beauvoir-type" rare-metal granite in this terrane is due to the lack of peraluminous protoliths that could produce rare-metal granite magmas by partial melting.



In the Q*3B*3F*3 diagram of (De la Roche et al., 1980) (Fig.16), the Tillik massif granites behave similarly as the albite-topaz-zinnwaldite (AZT) granite of Ebelekane. They display an inverse curve unlike the reference rare-metal granites (Beauvoir and Yichun).

Fig. 16. Q*3B*3F*3 diagram (De la Roche et al., 1980) for Tillik massif granitic facies, compared with reference granites (Beauvoir, Yichun, and Taourirtes du Hoggar).

DISCUSSION

The Tillik massif granites show homogeneous facies. From the center to the periphery of the massif, there is a noticeable decrease in potassium feldspar in favor of albite and a significant development of topaz, Fluorite, and lithiniferous micas. These facies are leucocratic granites, with a mineralogical composition represented by quartz with "snowball" structures characteristic of rare-metal granites.

From a mineralogical perspective, the columbo-tantalite deposits in this massif are enriched in niobium compared to tantalum (Nb>Ta). They exhibit a remarkable chemical zonation that records the history of magmatic crystallization. The cores of the crystals memorize the early magmatic stage (pre-stage), while the late magmatic stages are recorded by the margins.

From a geochemical perspective, the granites of the Tillik massif are strongly fractionated, peraluminous, poor in phosphate, and display relatively flat REE spectra with a pronounced anomaly in Eu. Moreover, geotectonic sites show that the different samples are projected into the intraplate granite of the collision domain and highlight the transition from the post-orogenic domain to the androgenic domain. Furthermore, these granites have crystallized rapidly at high temperatures and placed in shallow depths, constituting the most evolved suite of Alaskaites of the Taourirts of the Hoggar in the (Debon & Lefort, 1988) A-B diagram. Unlike the granites of reference (Beauvoir and Yichun), they exhibit an inverse curve in the Q*3B*3F*3 diagram of (De la Roche et al., 1980), suggesting a magma combination and blend.

One of the consequences of these mixing processes is that the Rare-Metal Granites in the Hoggar province (RMGh) are often poorly enriched in rare metals, as might be expected from their geochemical and mineralogical characteristics. Moreover, mixing can influence the specialization of some of these granites in other metals. For instance, the Be content of the Guerrioune, Tit n'Enir, Nahda, and Rechla beryl granites and pegmatites, and to a lesser extent, the Ebelekane, is related to the proportion of peralkaline magmas. This may also be the latest expression of "Taourirt" magmatism (Azzouni-Sekkal et al., 2003).

Based on the unusual geochemical behaviors, the RMGh, are believed to originate from a mix of different magmatic strains. These include a peraluminous strain that can produce RMG, corresponding to the most fractionated term of the "Taourirt" granites, and with a peralkaline tendency. Additionally, purely peralkaline granites of the same age can be found in the central Hoggar at Adjemamaye.

In the Hoggar rare-metal granite province, there are still no discoveries of the purest RMGh terms with significant mineralization so far. However, Rechla (with Li≈1600 ppm, Ta≈211ppm, Sn≈740 ppm, Zn≈200 ppm) and especially Ebelekane (with Li≈395 ppm, Ta≈306 ppm, Sn≈335 ppm) seem to be the least hybrid of the RMGh, according to (Kesraoui, 2005).

CONCLUSION

In this study, we presented the "Tillik" massif, one of the granite massifs of the Laouni region. The objective was to identify its petrographic, mineralogical, and geochemical characteristics.

At the end of this study, we can emphasize that the granites of the "Tillik" massif are to be classified among the Rare Metal Granites of Hoggar (RMGh) and come from a mixture of peraluminous, peralkaline magma which is the most fractionated of Taourirtes. However, they do not show any evidence of mixing magmas like those of Ebelekane and Rechla which are Tantalus granites. Unlike references, these granites are little enriched in rare metals (Beauvoir and Yichun).

In Hoggar, research on rare metals must be oriented towards post-orogenic granites with the potential to contain proven but little-studied mineralization, such as the Ebelekan massif located in the terrane (Assodé – Issalane) of orientalHoggar rich in Ta, the Guerioune massif for the Be-Ta-Nb, the and Rechla

for the Be-Li-Ta. The latter will be the subject of a subsequent study where its petrographic, mineralogical, and geochemical characteristics will be studied.

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Conflict of Interest
The authors declare no conflict of interest.

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Original scientific paper

Reduction of Hexavalent Chromium by Nano Zero-Valent Iron

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ABSTRACT: Hexavalent chromium is a toxic form of chromium that has significant health and environmental implications. Reducing hexavalent chromium to trivalent chromium is a crucial step in immobilizing and removing Cr(VI) from water resources. Nano zero-valent iron (nZVI) as an electron-donating agent was used for Cr(VI) reduction in aqueous solution. The effect of contact time and initial concentration of nano zero-valent iron on Cr(VI) reduction was studied. The process of Cr(VI) reduction was designed and optimized using response surface methodology. The results indicated an enhancement in the Cr(VI) reduction ratio with increasing initial concentration of nano zero-valent iron and contact time. A second-order polynomial equation was used to model the correlation between the independent and dependent variables. The utilized model effectively predicted the response variable based on the input variables with a high coefficient of determination (R^2) of 0.9475 and a correlation coefficient (R) of 0.9734. Additionally, the accuracy of the fitted model was demonstrated by the low values of the mean squared error (MSE) at 0.04315 and the sum of squared errors (SSE) at 0.06562. The optimal conditions for reducing Cr(VI) in aqueous solution using nano zero-valent iron were determined to be an initial nZVI concentration of 15 mg/L and a contact time of 209 min.

Keywords: hexavalent chromium Cr(VI), nano zero-valent iron (nZVI), reduction, process design and optimization

INTRODUCTION

Pollution of the environment and water resources by inorganic pollutants, particularly heavy metals and metalloids, poses a significant challenge and risk to the environmental integrity and human health. Chromium is a potentially hazardous metal found in surface and groundwater, originating from both natural processes and human activities (Mitra et al, 2022). Chromium is utilized in various industrial processes, including galvanization, electroplating, production of stainless steel, pigments, paints, and other industrial applications. Significant quantities of chromium-based compounds are released and dumped from industrial establishments into the environment through liquid, solid, and gaseous wastes (Ayele et al, 2021). Chromium can exist in several oxidation states in water resources, however, hexavalent chromium and trivalent chromium are the most common and stable forms that are found (Kotaś & Stasicka, 2000).

Hexavalent chromium Cr(VI) is highly soluble and mobile in aqueous solution and typically does not form insoluble compounds in water. It is more toxic and carcinogenic to humans and animals than trivalent chromium Cr(III). Cr(III) tends to form insoluble compounds or complexes with organic matter in water, reducing its mobility and bioavailability. In an aqueous solution at neutral pH, Cr(III) generally forms insoluble hydroxide precipitates (Barrera-Díaz et al, 2012; Ölmez, 2009). In this context, the reduction of Cr(VI) to Cr(III) is considered a feasible method and essential phase in the immobilization and ultimately the removal of Cr(VI) from the water contaminated with this hazardous pollutant (Dehghani et al, 2016).

Different methods for reducing Cr(VI), including chemical, electrochemical, and biological techniques, are employed to convert Cr(VI) into less toxic and mobile forms (Bandara et al, 2020; Butter et al, 2021; Wang et al, 2010). The selection of a specific method depends on various factors, such as the type

of contaminated water (surface, underground, or industrial), the volume of water to be treated, the process effectiveness, the goal efficiency, etc (Saravanan et al, 2021). Iron(II) chloride, iron(II) sulfate, sodium bisulfite, sulfur dioxide, ascorbic acid, and citric acid are frequently used as chemical agents for Cr(VI) reduction in aqueous solution. Each reducing agent has its advantages and limitations (Asgari et al, 2020; Pettine et al, 1998; Zaib et al, 2021).

In recent years, nano zero-valent iron (nZVI) has gained significant attention for its effectiveness in removing various pollutions from water resources and soil. This is primarily due to its high specific surface area and reactivity that enhance its ability to rapidly reduce or immobilize pollutants through reduction, adsorption, or catalytic processes. nZVI is a low-cost, environmental-friendly, and efficient solution for the remediation of contaminated groundwater (Wang et al, 2021). It can be applied in permeable reactive barriers or in-situ remediation of various contaminants in groundwater, including Cr(VI) (Zafar et al, 2021). Reducing Cr(VI) by nano zero-valent iron in an aqueous solution involves the adsorption of Cr(VI) on the surface of nanoparticles and the transfer of electrons from the nZVI to Cr(VI) (Qiu et al, 2020). Contact time, nZVI concentration, Cr(VI) concentration, temperature, pH of the solution, the chemical composition of the aqueous solution, and physicochemical properties of the used nZVI influence the reduction of Cr(VI) by nZVI. In general, the effect of operating parameters on the efficiency of the Cr(VI) reduction has mainly been conventionally analyzed and defined. Conventional methods of process optimization typically involve analysis of the influence of one factor at a time while keeping all other factors constant. The main limitation of this approach is the inability to determine the influence of interactions between independent variables (Gao et al, 2022; Niu et al, 2005; Zhang et al, 2020). Advanced statistical methods such as response surface methodology (RSM) can be used to determine the interaction between factors and identify optimal process conditions.

The response surface methodology is a statistical technique used for designing experiments, developing predictive models, and optimizing complex processes based on a limited number of experiments. This technique is established to explore the effects of multiple variables on one or more responses of interest. The primary objective of RSM is the development of predictive polynomial models that accurately describe the behavior of studied processes. One of the key advantages of RSM is its ability to efficiently identify the optimal combination of factor levels that maximize or minimize the response variable. Additionally, the RSM allows the visualization of the predictive models by creating response contour and surface plots (Hadiyat et al, 2022; Kumar & Reji, 2023; Yolmeh & Jafari, 2017).

In the presented study, nano zero-valent iron was used to reduce Cr(VI) in the model aqueous solution. The effect of contact time and initial nZVI concentration on the Cr(VI) reduction ratio was researched. The process was optimized using response surface methodology. Within the framework of this work, a specific system was designed for the highly efficient removal of Cr(VI) through its reduction to Cr(III), coupled with the subsequent optimization of process parameters. A predictive mathematical model for accurately calculating the efficiency of Cr(VI) reduction by nZVI in pH-neutral aqueous solutions contaminated with the pollutant at concentrations around 0.5 mg/L was developed. Additionally, the influence of the studied working parameters and their interaction on the response and optimal reduction region were determined.

MATERIALS AND METHODS

Reduction Of Cr(Vi) By Nano Zero-Valent Iron

The reduction of Cr(VI) to Cr(III) in an aqueous solution was performed in a 2000 mL laboratory glass beaker. Nano zero-valent iron used in this study was synthesized by reducing Fe(III) ions with sodium borohydride. For this purpose, 1.5 g of iron(III) chloride hexahydrate (for analysis, Merck) was dissolved in

83 mL of ethanol 77 %. The ethanol 77 % was prepared using ethanol 96 % (Ph.Eur., Alkaloid) and deionized water. The conductivity of the deionized water was less than 0.5 μS/cm. Then, 93 mL of 0.3 M sodium borohydride solution was prepared and added dropwise to the Fe(III) solution (2 drops per second). During the reaction process, the mixture was stirred in a 1000 mL glass beaker at a mixing speed of 300 rpm. After adding the entire borohydride solution, the mixture was stirred for an additional 15 minutes. Solid zero-valent iron nanoparticles were separated on filter paper (Macherey-Nagel MN640 DE) using vacuum filtration. The particles were washed with 250 mL of ethanol 96 %. The synthesized nZVI was dried in a vacuum desiccator at a pressure of 20 kPa and a temperature of 50°C for 7 h. Dried nZVI was stored in a vacuum bag.

The chromate aqueous solution with an initial Cr(VI) concentration of 0.5 mg/L was prepared and transferred into the beaker. The initial solution pH was adjusted to 7.0 using a 0.1 M solution of NaOH. Then, the nZVI was introduced into the solution. The reaction solution was stirred at a mixing speed of 1000 rpm and a temperature of 20°C. The effect of contact time and initial nZVI concentration on the Cr(VI) reduction was studied. The contact time was changed from 0 to 240 min, and the initial nZVI concentration was 5 to 15 mg/L. Cr(VI) reduction ratio was calculated following the equation:

$$\text{Cr(VI) reduction ratio} = C/C_0 \quad (1)$$

where C is the concentration of Cr(VI) at a specific time [mg/L], and C_0 is the initial Cr(VI) concentration [mg/L]. After each predetermined time interval, a 5 mL sample was withdrawn from the reactive solution and immediately filtered using a syringe filter with a pore size of 0.2 μm. The Cr(VI) concentration was determined with 1,5-diphenylcarbazide using a spectrophotometer (Spectroquant Prove 600) at 540 nm. The chromate test (Spectroquant, chromium (VI) method: photometric 0.010 - 3.00 mg/L) for the determination of Cr(VI) was employed. Each solution was prepared in accordance with the manufacturer's instructions described in the 1.14758.0001 procedure. A rectangular quartz glass cuvette with a path length of 10 mm was utilized for the analysis. A preprogrammed method (114758) in the spectrophotometer Prove 600 was used to measure the concentration of Cr(VI) in the samples.

Process Design and Optimization

A multilevel factorial design was used to optimize the process of Cr(VI) reduction in aqueous solution by nZVI. The contact time (t) and the initial nZVI concentration (C_{nZVI}) were selected as the most important independent factors that have a significant influence on the Cr(VI) reduction. Hence, these two parameters were used as experimental factors. The reduction ratio of Cr(VI) was employed as a response variable. The Statgraphics Centurion XV statistical software was introduced to fit the chosen model to the experimental data. A mathematical model was created to define the relationships between input variables and the response variable. The second-order polynomial equation was employed to find the critical point (minimum), following the equation:

$$y_{C/C0} = k_0 + k_1 t + k_2 C_{nZVI} + k_3 C_{nZVI} t + k_4 t^2 + k_5 {C_{nZVI}}^2 \quad (2)$$

where $y_{C/C0}$ is a predicted Cr(VI) reduction ratio, t is a contact time [min], C_{nZVI} is an initial nZVI concentration [mg/L], k_0, k_1, k_2, k_3, k_4, and k_5 are regression coefficients. The predictive accuracy of the model was estimated through the values of the mean absolute error (MAE), the standard error of estimate (SEE), the coefficient of correlation (R), and the coefficient of determination (R^2). Lower values of MAE and SEE and higher values of R and R^2 indicate better predictive performance.

RESULTS AND DISCUSSION

RSM Design of Cr(VI) Reduction by Nano Zero-Valent Iron

The efficiency of the Cr(VI) reduction in aqueous solution by zero-valent iron nanoparticles depends on several parameters: contact time, the concentration of Cr(VI), the concentration of nZVI, the pH of the solution, the temperature, etc. In this study, the effect of contact time and initial nZVI concentration on Cr(VI) reduction was investigated. Three different concentrations of nZVI were employed, while the initial Cr(VI) concentration was fixed at 0.5 mg/L. The reduction ratio of Cr(VI) in aqueous solution at different initial nZVI concentrations is illustrated in Figure 1.

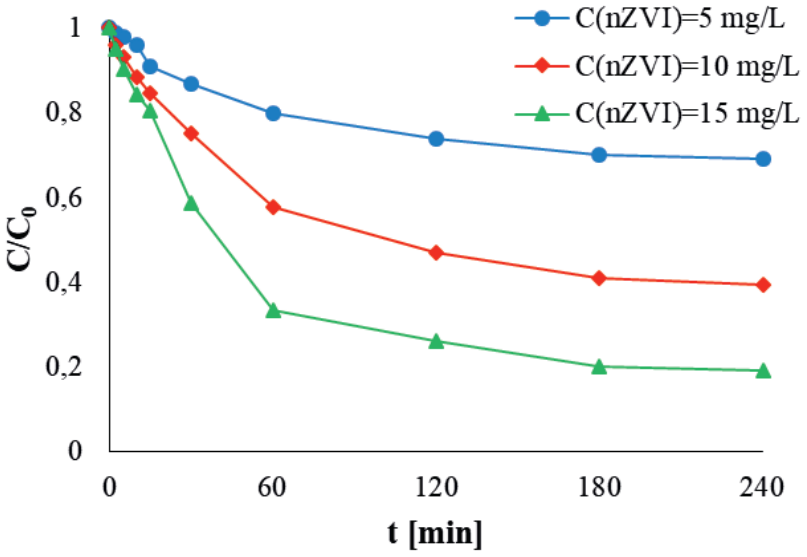

Figure 1. Reduction of Cr(VI) by nZVI at different initial nZVI concentrations

pH=7.0, T=20°C

Results showed that increasing the initial nZVI concentration leads to a significant improvement in the efficacy of Cr(VI) reduction and suggests a strong positive correlation between nZVI concentration and reduction efficiency. When 10 mg nZVI was introduced in the solution, the Cr(VI) reduction efficiency was 26.0 % at a contact time of 120 min and 31.0 % for 240 min. However, when the initial concentration of nZVI was increased to 15 mg/L, the Cr(VI) reduction increased to 81.0% after 240 min. Figure 1 shows that the reduction efficiency increases by increasing contact time.

The relationship between the independent variables and the dependent variable was determined using a second-order polynomial equation based on the experimental data. The model equation is presented in Equation 3:

$$y_{C/C0} = 1.12055 - 0.02235\ C_{nZVI} - 0.00021\ C_{nZVI}\ t + 0.00002\ t^2 + 0.00052\ C_{nZVI}{}^2 \quad (3)$$

The magnitude of the regression coefficient in the equation of the fitted model represented that the initial nZVI concentration and the contact time have a stronger influence on Cr(VI) reduction than contact time-squared, initial nZVI concentration-squared, and interaction between contact time and initial nZVI concentration. The initial nZVI concentration was determined to be the most important factor for the reduction of Cr(VI) by nZVI in aqueous solution. The analysis of variance (ANOVA) for the studied process is presented in Table 1.

Table 1. Analysis of variance for the response surface quadratic model

Source	Sum of Squares (SS)	Degrees of Freedom (Df)	Mean Square	F-ratio	P-value
A: Contact time	0.773371	1	0.773371	179.63	0.0000
B: Initial nZVI concentration	0.475582	1	0.475582	110.46	0.0000
AA	0.212776	1	0.212776	49.42	0.0000
AB	0.142784	1	0.142784	33.16	0.0000
BB	0.00112667	1	0.00112667	0.26	0.6136
Total error	0.103329	24	0.00430538		
Total (corr.)	1.96679	29			

The ANOVA table showed that 4 effects have P-values less than 0.05, indicating that they significantly differed from zero at the 95.0% confidence level. Several authors have reported developed mathematical models for the reduction and removal of Cr(VI) from aqueous solution by the implementation of nZVI-based material (Jing et al, 2021; Singh et al, 2011; Tong et al, 2022). The model reported in this article depicts the closed system: properties of pure nZVI-Cr(VI) and resulting 3D-RSM area. The interpretation of the obtained results strongly confirms the introduced novelty compared to already reported research: nZVI-based redox system and adequate optimization methodology. The response contour and surface plot were employed to visualize the predictive model and estimated response. The contour plot and response surface plot are given in Figures 2 and 3.

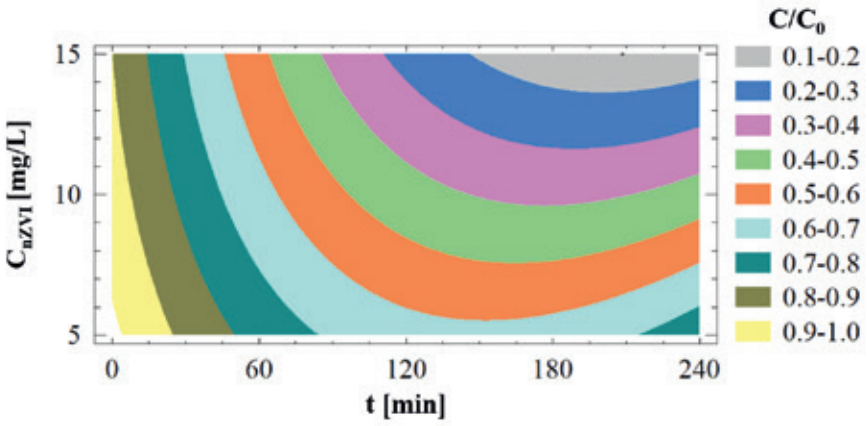

Figure 2. Couture plot for the effect of experimental factors on Cr(VI) reduction by nZVI

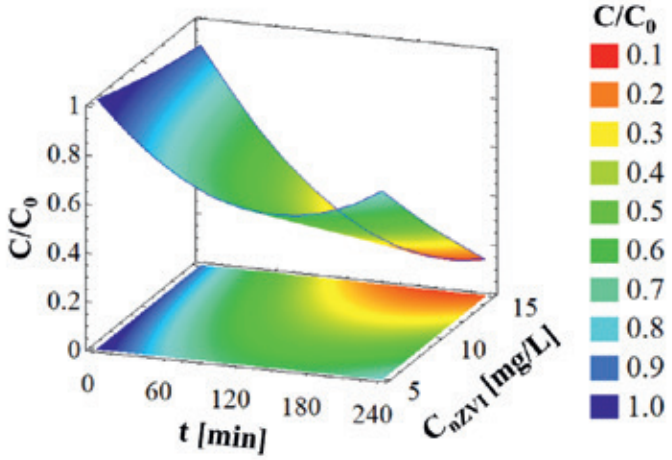

Figure 3. Response surface plot for the effect of experimental factors on Cr(VI) reduction by nZVI

The contour and response surface plots showed that the reduction of Cr(VI) significantly increased with increasing the initial nZVI concentration in the range of 5 to 15 mg/L, especially evidently after 60 min. Furthermore, plots suggested that the Cr(VI) reduction ratio significantly decreased for the process duration from 0 to 120 min, and after 180 min the Cr(VI) reduction asymptotically approaches a stationary state. The interaction effect of contact time and initial nZVI concentration on the response variable visually is given in Figure 4.

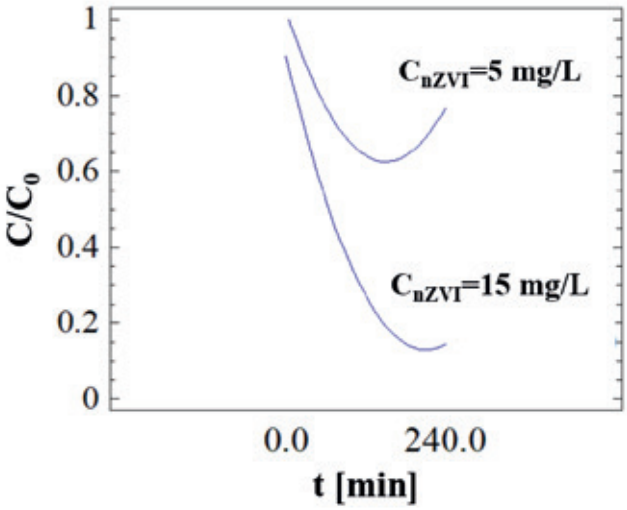

Figure 4. Interaction effect between contact time and initial nZVI concentration on the Cr(VI) reduction

In Figure 4, the x-axis represents contact time, the y-axis represents Cr(VI) reduction ratio, and the lines represent different levels of initial nZVI concentration. The placement of the curves signified that the effect of contact time on Cr(VI) reduction varies depending on the level of initial nZVI concentration, and vice versa.

The established model effectively predicted the reduction of Cr(VI) by nano zero-valent iron (nZVI) in aqueous solutions with a high coefficient of determination of 0.9475 and a correlation coefficient of 0.9734. Low values of MAE (0.04315) and SEE (0.06562) indicated that the model provided a good fit to the experimental data and could be effectively used for optimization purposes. Additionally, the scatter plot (Figure 5) showed that most points were close to the reference line, indicating a good correlation between predicted and observed values. The comparison between actual and predicted responses obtained by the developed model is illustrated in Figure 6.

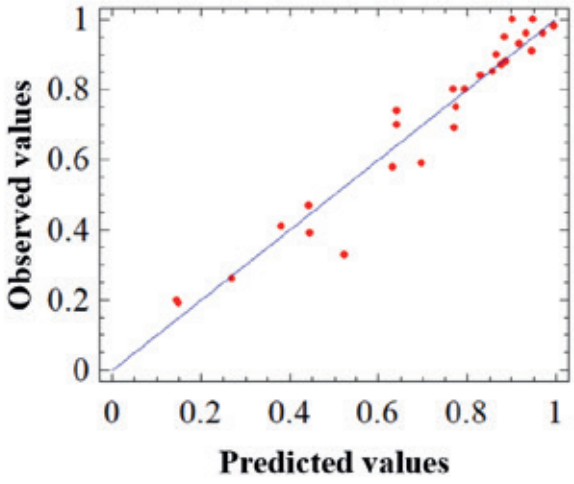

Figure 5. Scatter plot of predicted versus observed values

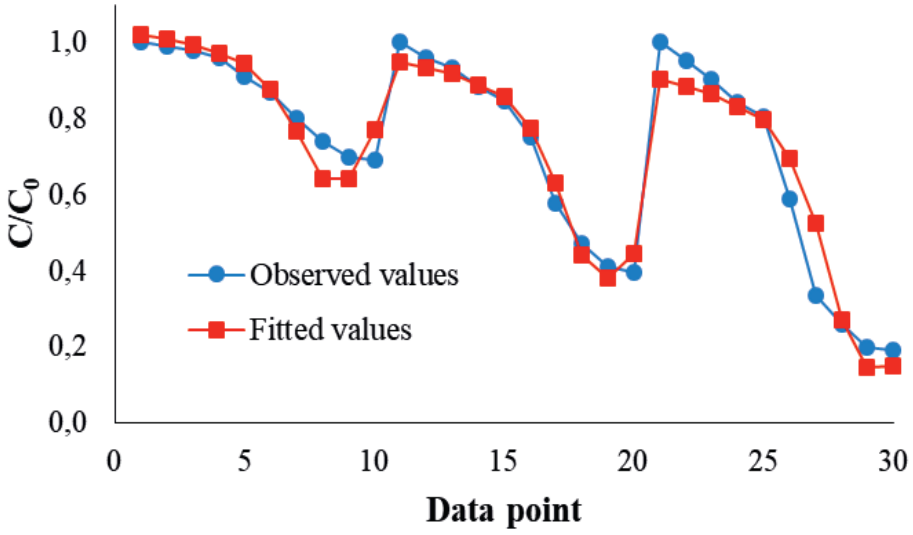

Figure 6. Comparison of model-predicted and actual values of Cr(VI) reduction

The design variables of contact time and initial nZVI concentration were utilized to determine the optimal process parameters as well as the minimal Cr(VI) reduction ratios. The optimal reduction ratio for Cr(VI) using nano-zero valent iron was 0.13, achieved under optimal conditions of 15 mg/L initial nZVI concentration and 209 min of contact time.

CONCLUSION

The study investigated the reduction of hexavalent chromium by nano zero-valent iron (nZVI) in an aqueous solution as a potential remediation technique. The effectiveness of nZVI in reducing Cr(-VI) concentrations was examined under various experimental conditions, including different initial nZVI concentrations and contact times. The reduction process was designed and optimized using response surface methodology to assess the influence of process parameters on the Cr(VI) reduction ratio while minimizing environmental impact and optimizing processing conditions. The applied model adequately fitted the experimental data with a high coefficient of determination (R^2=0.9475) and correlation coefficient (R=0.9734). Furthermore, low values of the mean absolute error (MSE=0.04315) and the sum of squared errors (SSE=0.06562) confirmed the ability and accuracy of the model in representing the relationship between the factors and the response. The results showed that the reduction of Cr(VI) significantly depended on the contact time and initial nZVI concentration. The optimal Cr(VI) reduction ratio was 0.13 at the initial nZVI concentration of 15 mg/L for 209 min.

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Review

Personalized Medicine in Oncology: Ethical Considerations and Current Practice

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ABSTRACT: Personalized Medicine aims to provide targeted therapy specifically designed according to inherited and/or acquired risk factors present in different subgroups of patients. One of the milestones in tumor research was the realization that tumors are much more complicated and dynamic than it was believed 20 years ago. From year to year, thanks to the extreme advances in molecular oncology, genomics and proteomics, our knowledge of tumors keeps growing, which has led to the emergence of new drugs that target the weaknesses od tumors. Molecular pathways, based on knowledge of genetic characteristics, have identified possible therapeutic targets for certain groups of patients within a seemingly unique clinical phenotype or disease. Stratifying complex and heterogeneous groups of patients in this way led to a better definition of disease subgroups, with a more precise risk-benefit ratio. Selecting patients who will respond to a given drug and avoiding exposure to potential side effects of patients who will not respond to therapy increases the effectiveness of the drug, reduces the risk of unnecessary side effects or drug interactions that could cause serious complications and significantly increase treatment costs. In parallel with the advancement of personalized medicine, with all its advantages, new ethical considerations are being raised, especially issues of patient privacy, confidentiality, data protection, and patients' rights to fairness. The training on how to handle moral and ethical dilemmas while taking into account social, religious, and local societal values and practices can be very beneficial for the healthcare professionals and treating oncologists.

Keywords: carcinogenesis, personalized medicine, ethical considerations

INTRODUCTION

Cancer is not a single disease. There are more than 200 types of cancer. The process of tumor formation (carcinogenesis) occurs in several stages (Nowell, 1976; Amin et al., 2017) as a result of the actions of a number of endogenous and exogenous factors that lead to the damage at the gene level. It can be triggered by chemical, physical and biological agents called carcinogens. The process of carcinogenesis occurs in four stages:

- initiation - exposure of the cell to the appropriate dose of carcinogens that leads to the formation of mutations as irreversible changes in the DNA. Initiation alone cannot lead to the formation of tumors;
- promotion - stimulation of the proliferation of altered cells;
- progression - the stage in which, due to the accumulation of genetic mutations, autonomic growth of the tumor occurs and the initiator and promoter are no longer needed;
- malignant neoplasm (cancer) - malignantly transformed cells have the ability to invade and metastasize.

Tumors in humans are thought to be of monoclonal origin, meaning they were formed from a single transformed cell that continues to divide while avoiding normal control mechanisms. Cell proliferation often depends on an external signal that reaches receptors on the cell membrane, from there it is transmitted through the membrane to the cytoplasm and finally reaches the nucleus where DNA synthesis

begins. Normal cell genes play an important role in every segment of this signaling pathway, and most of them encode proteins by which external signals encourage cells to divide, differentiate, or die. Based on their enzymatic activity, proteins are divided into growth factors, membrane and cytoplasm kinase protein, guanosine triphosphatase (GTF), nucleus proteins and other proteins in the cell. The cell growth signal is transmitted from the membrane receptor to the cytoplasm by phosphorylation of these proteins. Malignantly transformed cells have a specifically altered behavior compared to normal cells and their most important phenotypic characteristics are autonomy, clonality, anaplasia and the ability to metastasize. During growth, a number of new cells are formed from the primarily transformed cell, many of which acquire some new traits by creating new clones, so we can say that the tumor is actually a population of very heterogeneous cells. This diversity may refer to morphology, proliferation, antigenity, biochemical products, invasiveness, metastasis, and susceptibility to therapy. This heterogeneity can change over time, some clones disappear, others prevail, so the characteristics of tumors can also change completely. The transition of normal to a transformed cell carries with it the acquisition of innate genetic instability and more frequent mutations compared to normal cells and the continuous creation of numerous variants. Many tumors during growth show an increasing degree of malignancy (Hanahan & Weinberg, 2000). The consequence of sequential selection over time leads to the appearance of abnormal subtypes genetically and biologically prone to greater invasiveness and metastasis. At the molecular level, carcinogenesis is a multistage process that occurs with the progressive accumulation of genetic damage, whereby the accumulation of somatic mutations, and not the order of their occurrence, is considered to be responsible for the development of malignant disease. Mutations in at least five or more tumor-related genes are thought to be crucial in carcinogenesis. Genes that by their mutation directly lead to tumor formation are called protooncogenic or oncogenic genes and their products are needed for the formation and maintenance of a malignant condition. They can alter the interrelationship of cells, their growth, division and differentiation. They are divided into cellular oncogenes that represent DNA sequences that are capable of causing malignant cell transformation and cellular proto-oncogenes that are formed by changing the structure and expression of normal cellular genes, which are necessary in the regulation of vital biological processes of the cell. Malignant transformation requires not only the activation of oncogenes, but also the inactivation of a completely different group of genes – antioncogenes or tumor suppressor genes, whose protein products inhibit tumor growth and activate apoptosis (programmed cell death). The p-53 gene protein is the most important tumor suppressor gene, which loses its function through mutation and is believed to be the most commonly mutated gene in human malignancies. A major unresolved problem in the therapy of malignant disease stems from primary resistance to therapy. In every tumor there are those cells that are "dormant" for a long period of time and which, along with preserved internal metabolic activity and mitochondrial metabolism, are insensitive to chemotherapy, because they are in a state of autophagy. In immunotherapy, primary resistance is due to the chemical barriers that the tumor establishes by producing growth factors and cytokines that T cells cannot overcome and reach the tumor. There are other causes of tumor cell resistance, e.g. when the T lymphocyte population is unable to act ("bad T lymphocytes") or when the number of active T lymphocytes is minor, which hinders interaction and causes a heterogeneous therapeutic response. One of the milestones in tumor research was the realization that tumors are much more complicated and dynamic than it was believed 20 years ago. From year to year, thanks to the extreme advances in molecular oncology, genomics and proteomics, our knowledge of tumors keeps growing, which has led to the emergence of new drugs that target the weaknesses od tumors. About 650 oncogenes associated with the tumor have been found, it is known that the growth and development of tumors often rests on blocking tumor suppressor genes, so today's research is largely focused on testing substances that establish the activity of the suppressor gene or, in turn, inhibit

oncogenes. In fact, oncology therapy is being developed today in the direction of targeted treatment or immunological control of tumors. According to today's indicators, if all the knowledge of primary prevention were applied, a third of malignant tumors in humans could be prevented; if early detection knowledge were applied a third would be curable; and if today's knowledge of immunology and signaling pathways in carcinogenesis were applied, a third of malignant diseases could be controlled for years while preserving the quality of life (Belikov, 2017; Amin et al., 2017).

Epidemiological data

Cancer is a devastating disease, and epidemiological data are worrying: 12 million people are diagnosed with cancer every year (32,000 every day) (Thun, DeLancey, Center, Jemal, & Ward, 2010).; nearly 8 million people die from cancer every year (20,000 deaths a day, 14 people every minute). The number of people who are diagnosed with cancer is predicted to increase by 69% from 2008 to 2030. *European Alliance for Personalized Medicine Report from Irish Presidency Conference* 2013, and World Cancer Report 2014, (McGuire, 2015) encourage urgent action, given the following factors:

- The global cancer burden has doubled over the last 25 years and is set to double again before 2030 (Executive Summary)
- As well as incidence and mortality increasing, prevalence is rising even more quickly, as more patients are alive within five years of diagnosis
- The worldwide cost of cancer due to premature death and disability is $895 billion (not including direct medical costs) (p. 299)
- Additionally, the proportion of the population in low- and medium-income countries aged over 65 is expected to increase by 5-10% (p. 450)
- In view of the strong association between cancer rates and age, these will combine to increase the cancer burden by 2030, with low- and medium-income countries most affected (p. 450)

Personalized Medicine

Personalized Medicine aims to provide targeted therapy specifically designed according to inherited and/or acquired risk factors present in different subgroups of patients. The foundations for this approach lie in the results of research that determine the origin of the disease at the molecular level, and thus provide insight into the complexity of the factors that lead to the occurrence of the disease.

A definition by European Alliance for Personalized Medicine (EAPM, 2013) states that personalized medicine most frequently refers to a medical model using molecular profiling for tailoring the right therapeutic strategy for the right person at the right time, and/or to determine the predisposition to disease and/or to deliver timely and stratified prevention. It may also involve imaging and other technologies.

From the very beginning of medicine, throughout its history, the most important goal has been to understand the basic mechanism that leads to disease and, based on these findings, to create appropriate therapeutic approaches. Due to the lack of pathophysiological knowledge, advances in medicine were based on an empirical approach and, consequently, pharmacology was guided by the idea of creating one or more medical products that treat a large population of patients "infected" with a single disease. This one-size-fits-all approach was beneficial for certain medical conditions, such as pain or headaches, but over time it became clear that diseases such as different types of malignancies were difficult to fit into this classic doctrinal approach (Spear, Heath-Chiozzi, & Huff 2001). In the final two decades of the last century, the therapeutic approach focused on the abnormality of the malignant cell itself, on signal transduction processes and protein traffic routes that regulate cell functions. A number of tyrosine and serine threonine

kinase inhibitors and monoclonal antibodies targeting signal receptors were researched. Some of them showed antitumor activity and through clinical research achieved inclusion in standard therapeutic protocols, but most of the tested substances that showed antitumor activity in basic studies did not confirm this in clinical studies, i.e. did not achieve a better therapeutic effect than classical chemotherapy. However, even this small "amount of success" has produced a strong optimism in the world of oncologists about the future of the treatment of malignant diseases. According to this optimistic concept, it is predicted that future patients will undergo only needle biopsy of the tumor for the diagnosis to be established and, based on the genetic characteristics of the tumor, an active successful therapeutic protocol will be applied. We already have genetic tests for certain tumors and for certain genetic changes that direct us to the choice of therapy and the favorable outcome of treatment.

Personalized medicine-a change in the treatment paradigm

Molecular targeted (biological) therapy is a completely new form of treatment that requires comprehensive information about the origin of the disease at the molecular level and complete insight into the complexity of the factors that lead to the onset of the disease. The modern, generally accepted term for this new direction in oncological treatment is "personalized medicine", which in literature goes by various synonyms - stratified, precise, molecular, genomic or tailored medicine (Roden & Tyndale, 2013; Biweber, 2013; Shen, & Hwang, 2010; Ross et al., 2003; Eng, 2013; Smart, Martin & Parker, 2004). In a narrow sense, personalized medicine is the systematic use of information about the individual patient with the aim of choosing the optimal prevention and treatment. The importance of this approach in medicine stems from the fact that each person has their own specific genomic-proteomic, i.e. molecular profile, which is responsible for the specificity and severity of their disease, as well as the reaction of that person to drugs. The ultimate goal of personalized medicine early diagnosis, before the onset of clinical symptoms, which would ensure timely introduction of optimal preventive measures. When the disease becomes clinically visible and with symptoms, personalized medicine aims to identify the characteristic and individual biomarker profile, endophenotype, and accordingly adapt and specify the ideal curative therapy (Eng, 2013; Smart, Martin & Parker, 2004). In this way, the prognosis for malignant tumors and other diseases with a fatal outcome could change drastically.

Personalized therapy and nanomedicine

In order for personalized or precise medicine to be developed, advances in analytical methods called high-flow methods are necessary. Their introduction into medicine enables the creation of real personalized medicine, because it directly or indirectly ensures the application of genomic and proteomic research with the aim of enabling prevention and treatment tailored to each person.

At the beginning of the 21st century, the knowledge we gained on the human genome brought an accelerated advancement of bioanalytical technologies also known as "omics" (Ocana, & Pandiella, 2010). The "omics" methods (transcriptomics, proteomics, metabolomics, lipidomics, glycomics, structural genomics, etc.) are based on nanotechnologies engaged in the research, development and application of structures, devices and systems up to 100 nanometers in size (1 nm = 10^{-9} m), i.e. atoms, molecules and macromolecules. The application of nanotechnology in the treatment, diagnosis, monitoring and control of biological systems is defined under the name nanomedicine. It studies nanoparticles that act as biological mimetics (e.g., functionalized carbon nanotubes), nanomachines (e.g., those made of DNA), nanofibers, and polymer nanostructures that serve as biomaterials (e.g., nanoporous membranes), as well as various devices that operate at the nanoscale (e.g., microchip drug delivery devices), capable of targeted delivery

of drugs, genetic materials and diagnostic agents to specific cells and extracellular spaces in the body. One of the main goals of nanomedicine is the research of rational and targeted delivery of therapeutic and diagnostic agents with precise identification of targets (cells and receptors), as well as the selection of appropriate nano-carriers that should ensure the achievement of the desired goal with as few side effects as possible. For optical detection, quantum dots (nanoparticles) are used that can be adjusted to emit light of a certain color, so they have already been used in some research to monitor the metastasis of tumor cells. The application of nano-tools could contribute to the understanding of complex regulatory and signaling networks that control the behavior of cells in physiological and pathological conditions. The application of the mentioned technologies in biomedicine enables the knowledge of the factors involved in the development of the disease on an individual level, i.e. for each individual patient. High-flow methods and nanomedicine represent the technological base of "omics", and "omics" are comprehensive methods that obtain information in one step or analysis, i.e. characterization of all or most members of a certain family of molecules. Transcriptomics is a systematic analysis of all genes in an organism, and proteomics is a systematic analysis of protein expression that includes the separation, identification and characterization of proteins in an organism. The term proteome, which has been used since 1994, as the linguistic equivalent of the term genome (protein complement to a genome), denotes all the proteins that the genome expresses during life (Chen, & Snyder, 2013). Proteins are integral parts of molecular complexes, signaling networks and organelles that are functional parts and important regulators of cellular processes, which includes "circulation" of proteins (recycling and degradation), post-translational modifications, subcellular localization, and the so-called protein-protein interactions. Protein-protein interaction leads to the formation of complexes that are involved in the transmission of signals through the cell. Based on our knowledge on genomics and proteomics, we got to know the molecular nature of the disease better and developed a "cellular map", which resulted in our better understanding of malignant diseases through the expression, interaction and function of proteins. These findings further helped us in the process of diagnosis, classification, prognosis and assessment of the therapeutic result, which leads us to real personalized medicine based on the patient's proteomic profile. Progress in understanding the genetic and epigenetic complexities of clinical phenotypes has brought numerous information with possible predictive, diagnostic and prognostic value, and at the same time helped our understanding of the genetic background of many monogenetic and genetically complex diseases (Bieber, & Broich, 2013; Dorfman, Khayat, Sieminowski, Golden, & Lyons 2013; van den Broek, Visser, Allaart, & Huizinga, 2013). Molecular pathways, based on knowledge of genetic characteristics, have identified possible therapeutic targets for certain groups of patients within a seemingly unique clinical phenotype or disease (Trusheim, Berndt, & Douglas, 2007). Stratifying complex and heterogeneous groups of patients in this way led to a better definition of disease subgroups, with a more precise risk-benefit ratio (Olson et al., 2014; Suh et al., 2013). Selecting patients who will respond to a given drug and avoiding exposure to potential side effects of patients who will not respond to therapy increases the effectiveness of the drug, reduces the risk of unnecessary side effects or drug interactions that could cause serious complications and significantly increase treatment costs (Fernald, Capriotti, Daneshjou, Karczewski, & Altman, 2011). EAPM (The European Alliance for Personalized Medicine) was launched in March 2012, with the aim of improving patient care by accelerating the development, delivery and uptake of personalized medicine and earlier diagnostics, through consensus. EAPM states that in practice, rather than having a unique treatment for each individual person, patients are sub-divided into groups based on their "molecular make up", i.e. using biomarkers (Grice et al., 2009). This definition does not mention any of genetic or genomic profiling, primarily referring to a pharmacogenetic and pharmacogenomic technologies (Lazarou, Pomeranz, & Corey, 1998). Genetics is the study of heredity and genomics is defined as the study of genes and their

functions, and related techniques. Thus, pharmacogenetics refers to genetic differences/genetic variations in metabolic pathways that can affect individual responses to drugs, while pharmacogenomics is more complex and it analyzes entire genome – the complete set of DNA within a single cell of an organism. And, if we take into account that adverse drug reactions (ADRs) rank as fourth leading cause of death in United States and that ADRs are significant cause of morbidity, with the fact that many diseases have a genetic component with tests already available, the role of pharmacogenetic, pharmacogenomics and other genetic and genomic research is priceless.

The Future of Personalized Medicine

Global analyses of genomes and proteomes are being intensively developed and technologically and methodologically improved, and their application is entering clinical medicine. The most important means on which personalized medicine will be based in the future are biomarkers (World Health Organization, 2006; Olson et al., 2014; Suh et al., 2013; Fernald, Capriotti, Daneshjou, Karczewski, Altman, 2011). Tremendous progress in various "omics" fields has triggered numerous studies aimed at the improved understanding of the genetic, epigenetic and other pathophysiological mechanisms that lead to the complexity of diseases with wide clinical and heterogeneous phenotypes. These technologies will provide a step-by-step discovery of new biomarkers, allowing endophenotype-based stratification of patients according to elaborated criteria. Beyond that aspect of research, much effort will go into evaluating biomarkers until they are accepted for clinical use (Roden, & Tyndale, 2013). Identification of relevant biomarkers and their validation will be available only when biological samples from biobanks are thoroughly processed and confirmed with clinical phenotype information (Suh et al., 2013). The enormous amount of data that must be available in this context is highly dependent on sophisticated bioinformatics-based algorithms (Trusheim, Berndt, & Douglas, 2007; Olson et al., 2014;Suh et al., 2013). Therefore, establishing and combining high-quality biobanks with collected representative biological samples, high-quality phenotype information, and innovations in the biotechnological system are crucial in biomarker research and validation. Biomarkers are tumor- or host-related factors linked to the biological behavior of tumors and the prognosis for the patient. Biomarker detection aims to: aid in establishing a diagnosis with a more precise determination of the stage of the disease, aid in the selection of patient treatment, and predict or monitor the response to therapy. In clinical trials, with the help of biomarkers, the pharmacological or biological mechanism of action of drugs can be confirmed, biomarkers can influence the development of test protocols, can help in the selection of patients and the appropriate dose of the drug, and can influence the reduction of the risk of unwanted events.

Endophenotype-Based Stratification of Heterogeneous Clinical Phenotype and Implications for Personalized Medicine

Each disease is determined by a more or less wide range of individual symptoms that complement the clinical phenotype, while having the same diagnosis. Clinical heterogeneity is often a mirror of complex pathophysiological mechanisms that may have different genetic and epigenetic origins. Similarly, the heterogeneity of clinical response to classical therapy includes the risk of giving drugs with serious side effects to patients whose body will not respond to those drugs (Grice et al., 2009). This is a special and important aspect for which medicine is trying to find an answer. Advances in our knowledge of the genetic and epigenetic background and diversity of pathophysiological mechanisms will lead us to separate complex phenotypes into much clearer and homogenized defined subgroups that will be characterized by biomarker and endophenotype profiles. Therefore, it is realistic to expect that most diseases will be redefined in subgroups according to molecular taxonomy based on biomarkers (Momper, & Wagner, 2014; Bieber, 2012). In ad-

dition to genetic and epigenetic information, as well as knowledge about biochemical and immunological pathways, numerous other facts will be integrated, such as type of diet, lifestyle, exposure to environmental factors and many others (Morgan, & Huttenhower, 2012). Only then will the individual profile of each patient be better understood, and we can hope that in the future we will make a turn from the current approach of disease treatment to a preventive approach. The current approach to personalized medicine requires the interaction of numerous participants in the process, which brings with it numerous challenges. Success is strongly dependent on progress in identifying relevant biomarkers, which allow us to stratify complex phenotypes and identify those patients who will have the best response to a given drug with the lowest possible side effects. Finally, it should be mentioned that personalized medicine includes significant ethical and socioeconomic issues that are important at all levels (Kesselheim, & Shiu, 2014; Schleidgen, & Marckmann, 2013; Phillips et al., 2014). The development of personalized medicine requires large population studies that will collect data on groups of people with the same or similar characteristics, from the environment in which they live and where they were born, lifestyle, as well as data obtained by collecting biological samples from biobanks. The combination of these data will be the basis for creating a more detailed classification of disease subtypes and will help us better understand the responsibility of the biological basis and environmental factors for each individual.

The relationship between financial investment and ethics in personalized oncology

Cancer is expensive. Worldwide, the financial cost to an individual has been shown to be significant. The European Commission (EC) has allocated around *€ 900 million* to *personalized medicine*, enabling research over the latest 5-year period via the Health Theme of the Seventh EU Framework Programme for Research and Technological Development (FP7). Or, if we look at how drug prices are rising: in 2000, the average cost of one year of a new systemic cancer therapy (SACT) was less than $10,000, while 20 years later, a new drug for a similar indication costs more than $100,000 for the same duration treatment. French National Cancer Institute spent *€ 1,7 million* on testing for EGFR biomarkers in 16.724 lung cancer patients – the tests showed that only 1724 patients (10% of the tested individuals) would respond to the available treatment (gefetinib or erlotinib). The savings for not treating 15.000 nonresponders amounted to € 69 million based on the median *treatment period of 8 weeks.* Therefore, the cost of personalized medicine in oncology is increasing. On the other hand, the conflicting priorities of the pharmaceutical industry, local and national governments, the international medical community, and patients need to be reviewed and balanced. So in order to optimize the care of cancer patients, ethical considerations from the physician's point of view must be taken into account.

PERSONALIZED MEDICINE IN ONCOLOGY: ETHICAL CONSIDERATIONS

In parallel with the advancement of personalized medicine, with all its advantages, new ethical considerations are being raised, especially issues of patient privacy, confidentiality, data protection, and patients' rights to fairness. Personalized medicine benefits all stakeholders in healthcare.

The beginning of ethical considerations takes us back to 1951, when 30-year-old Henrietta Lacks, the descendant of freed slaves, was diagnosed with cervical cancer, a strangely aggressive type, unlike any her doctor had ever seen. He took a small tissue sample without her knowledge or consent. A scientist put that sample into a test tube, and, though Henrietta died eight months later, her cells - known worldwide as HeLa - are still alive today. They became the first immortal human cell line ever grown in culture and one of the most important tools in medicine: Research on HeLa was vital to the development of the polio vac-

cine, as well as drugs for treating herpes, leukemia, influenza, hemophilia and Parkinson's disease; it helped uncover the secrets of cancer and the effects of the atom bomb and led to important advances like cloning, "in vitro" fertilization, and gene mapping.

Since 2001, five Nobel Prizes have been awarded for research involving HeLa cells. There's no way of knowing exactly how many of Henrietta's cells are alive today. One scientist estimates that if you could pile all the HeLa cells ever grown onto a scale, they would weigh more than 50 million metric tons—the equivalent of at least 100 Empire State Buildings.

Today, nearly 60 years after Henrietta's death, her body lies in an unmarked grave in Clover, Virginia. But her cells are still among the most widely used in laboratories worldwide, bought and sold by the billions. Those cells have done wonders for science, and Henrietta's legacy involves the birth of bioethics.

The medical and ethical case of Henrietta Lacks has been described in the bestseller "The Immortal Life of Henrietta Lacks" by Rebecca Skloot. This is a bestseller that takes readers on an extraordinary journey, from the "colored" ward of Johns Hopkins Hospital in the 1950s to stark white laboratories with freezers filled with HeLa cells, from Henrietta's small, dying hometown of Clover, Virginia, to East Baltimore today, where her children and grandchildren live and struggle with the legacy of her cells.

The complete genome of the HeLa cells was sequenced and published on 11 March 2013 without the Lacks family's knowledge (Koelsch, Przewrocka, & Keeling, 2013; Landry et al., 2013). After concerns were raised by the family, the authors voluntarily withheld access to the sequence data (Callaway, 2013[a]).

It is clear that the main dedication of physicians has always been to provide the best possible care for their patients. The ethical argument supporting techniques used for personalized medicine at the beginning was the need to reduce the incidence of mortality and morbidity caused by ADRs with later improvement of efficacy and, finally, with diagnosis of different diseases and tumor subtypes.

And finally, in order to further reflect on this topic, we remind you of important declarations:

- A Declaration of Geneva (May 2006) states: "The health of my patient will be my first consideration; I will respect the secrets that are confided in me, even after the patient has died."
- Modern version of Hippocratic Oath written by Louis Lasagna (1964) states: I will respect the privacy of my patients, for their problems are not disclosed to me that the world may know.

CONCLUSION

In order to fully understand the real impacts of personalized medicine in oncology both on the recipients and on the health system, a broad ethical analysis is also necessary, which will take into account the specificities of cancer care and critically evaluate the scientific progress of personalized medicine in oncology.

A fundamental issue that underlies the struggle within the oncology community is that there is no consensus about what defines value in cancer care. One definition of value is that the benefits in expected life extension and improved quality of life are obtained at a reasonable cost. The professional norm is that the first and foremost responsibility of oncologists is to do what is best for their patients. This norm is eroding in the face of the ever-increasing growth of health care costs, but it still influences the practice of many oncologists.

Additionally, in recent years, emphasis has been focused on professionalism, justice, dignity, empathy, truthfulness and honesty, which are crucial in cancer and are an essential aspect of medical care. The treating doctor have the responsibility of safeguarding the patient's privacy and confidentiality and this forms the basis of any doctor-patient relationship. Breach of confidentiality is a grave violation of an individual's human rights (Callaway, 2013[b]; Storm et al., 2005; Coleman, Evans, & Barrett, 2003). While "

the beneficence" and "non-maleficence" prioritise the rights and welfare of the patient, "autonomy" refers to the individual's right to choose and pursue whatever they like. In that situations adhering to the four fundamental bioethical principles—respect for "autonomy, non-maleficence, beneficence, and justice"—proposed by Beauchamp and Childress (1994)—help decision-makers reach morally sound conclusions in the face of tremendous difficulty (Soumita, Vivek, & Bhattacharya, 2019). And another way of looking at it brings us to concerns about the privacy and security of big data, including genetic data, especially in the context of commercial genetic testing services.

Conflict of interest
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Review

Management of Healthcare Worker's Communication Aspects Physiotherapist

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Abstract: The healthcare system, as part of the general social system, has developed and followed the general social and economic development, the development of thoughts, and new knowledge. Communication is seen as an inseparable factor of the whole socio-economic system. The health sector was unprepared for all the changes that were rapidly developing on a global level and in doing so, encountered the notions of sustainability and survival. The aim of this paper is based on the overview of the overall aspiration to understand the importance of communication of healthcare workers with a focus on managing the physiotherapist's communication in terms of communication during preparation for training as well as care of sports injuries. An important role is played by a multidisciplinary team, which usually consists of a club doctor, physiotherapist, and competitor. The main focus of the work is the role and importance of physiotherapists in supporting doctors as well as health improvement measures before, during, and after medical therapy. Therefore, in all three phases, communication is very important before, during, and after the completed treatment.

Keywords: health management, communication, physiotherapist

INTRODUCTION

Until a few years ago, management had a negative connotation, but today, according to the example of developed countries, this word is becoming more and more popular. Thanks to the development of company management, they have become more flexible and resistant to the negative effects of the economic environment. Health activity is by its nature very intensive, and therefore the costs of doing business within this activity have a progressive growth tendency. (Gereke, 1998)

New approaches and monitoring of modern business trends have become imperative due to the emergence of new circumstances on a global level (Corona virus pandemic, accelerated development of digital communications and media, the expansion of the cryptocurrency market, climate change, increasing tensions between the West and East in the political sense). There was a need for constant adjustment. One of the main problems of modern business is the adoption of a different business model, the focus of which is directed in the long term. The health sector represents the broadest concept that includes everything related to health, starting from education to agriculture and urban life. For example, the time in which all healthcare workers were guided by ethical principles and principles of humanity has long passed. Terms that healthcare has labeled as unethical and inhumane (market, management, marketing...) have come to the fore. That is why an analysis of the need to introduce modern management concepts such as the core competence concept, knowledge management, and the TQM concept was done, after which it was concluded that there is a great need for such an approach. (Ernjaković, 2022)

Follett defined management as an art, basing that determination mainly on the fact that management involves skills to some extent. Another author, Henry M. Boettinger, a management lecturer, also advocates the view that management is an art. (Bjegović, 2001)

The initiation and implementation of the Health for All strategy by the year 2000 through the healthcare system protection affect attempts to reform the health system based on that strategy, according to

which, the organization's objective is to attain highest level of health possible for all people. The declaration was signed by the representatives of 134 countries. It can be said that even up to a century ago, organized and developed healthcare systems in the modern sense almost didn't even exist. In the global health strategy for all until the year 2000, the following basic principles for the development of the health system were proposed:

- The health system should include the entire population on the basis of unity and reciprocity.
- It should include parts from the health sector, but also from other related sectors whose actions contribute to health.
- Primary health care should consist of at least the essential elements published in the Declaration from Alma-Ata.
- At intermediate levels, more complex and specialized problems should be solved in protection, as well as to implement logistical assistance. Staff educated and schooled at these levels should continuously train primary care staff as well as provide assistance and give recommendations to communities and health workers, in order to solve practical problems related to all aspects of primary health care. (Mićović, 2008)

Responsibility for the development of the health system and its functioning is becoming more important every day, with multiple topics discussed at all levels, from global to local. That responsibility was relatively small in the initial development of the system, but rapidly "grows" in developed systems, both because of its social and economic importance. All these enumerated determinations affect the organization, financing, management, and management of the health system.

LITERATURE REVIEW

If we look around, we can easily notice that the world would not function without communication. How could we express our thoughts and what we want unless we say it, show it, and touch it? Therefore, the business world could not function without interpersonal communication either, especially in health institutions. It is very important for every healthcare institution to invest enough funds in activities, such as health service promotion. Teamwork, health managers, and employees contributed to the development of the health institution. (Vrućan, 2022)

A healthcare worker is one who delivers care and services to the sick and ailing either directly as doctors and nurses or indirectly as aides, helpers, laboratory technicians, or even medical waste handlers. There are approximately 59 million healthcare workers worldwide. Recognizing the vital role played by health care workers as "the most valuable resource for health" the World Health Organization (WHO) had declared the years 2006 to 2015 as the "The decade of the human resources for health." (Joseph & Joseph, 2016)

A common occurrence in every health facility, regardless of region, was a high percentage of collaboration with colleagues, which required the use of medical and nursing documentation as a source of a large amount of useful information and striving to create comfortable working conditions without unnecessary stress. High pressure, little time, and a lot of work could influence healthcare workers to cut back communication with patients or colleagues. Empathy was also very important because the targeted population was very sensitive due to the specificity of the condition (illness, hospitalization, etc.) (Segic, 2011)

Therapeutic touch has played an important part in human civilization and continues to contribute to our social relations and individual identities. Therapeutic touch has been a vital component in the development and definition of physiotherapy practice and continues to be one of the profession's principal distinguishing competencies. (Nicholls & Holme, 2012)

In taking care of sports injuries, an important role is played by a multidisciplinary team, which usually consists of a club doctor and physiotherapist. In the care of athletes after injury with pharmacological therapy, physical therapy also plays a key role. The role of the physiotherapist is based on a thorough physiotherapy assessment of the patient and modeling and adaptation of the treatment to the patient. (Stojanović, 2023)

Physiotherapy aims to provide maximum movement as well as functional abilities of the human body through various methods of therapeutic procedures and training. Most football teams use some form of physiotherapy support in training or matches. A physiotherapist for football players, on the one hand, is responsible for the first medical aid for the entire team, and on the other hand, takes care of appropriate therapeutic measures in the regeneration and player injury phase. Physiotherapy does not replace the team doctor, but focuses primarily on physiotherapeutic treatments, which may precede medical measures. The main focus of the physiotherapist is to support the doctors with measures for health improvement before, during, or after medical therapy. A physiotherapist can use different treatment methods such as applications of fascia therapy, movement therapy - manual therapy or osteopathic procedures as well as various others for the purpose of health and recovery of football players. Because of heavy physical exertion, injuries to football players in training or during the match cannot be ruled out, there is a significant risk of injury to the entire musculoskeletal system. In case of disease symptoms or injury, especially of the muscular, ligamentous, and bony structures, a team doctor and physiotherapist are required. Both initiate medical first aid measures, with the physiotherapist taking into account the maintenance or restoration of the player's mobility. After an injury, the physiotherapist's job is to ensure that appropriate rehabilitation measures ensure that the player has as little pain as possible and recovers quickly to their old capacity. In the majority of cases, diagnostic examinations of football players are carried out immediately (MRI or Ultrasound diagnostic-musculoskeletal, if necessary, detailed tests with contrast means). (Stojanović, 2023)

In physical therapy, communication that actively involves the patient is considered the basis of patient-centered treatment. Communication research in physical therapy highlights how the patients' ability to actively participate is often limited by the therapist's focus on the biomedical facts and clinical tasks. (Ahlsen & Nilsen , 2022)

Lack of clarity regarding effective communication behavior in chronic pain management is an obstacle to the application of physical therapy approaches based on psychological information that relies on competent communication from physical therapist providers. (Chapman, Woo, & Mal, 2022)

In the world of medical professions, communication is key in the patient-provider relationship. In physical therapy, as well as all other medical professions, this fact is true. As a physical therapist, your job is to assess and treat any pain or mobility problems your patient has, and at the same time, you need the patient to trust you, to feel comfortable talking to you and to be in your immediate vicinity. While most communication is verbal, for example: "How does that feel?" or "My right knee hurts," that's not the only way communication takes place. I have found that non-verbal communication, such as reading body language, is also essential to the patient-therapist relationship and can be just as important as the verbal conversation between the two. (Belber, 2020)

'Communication' may act as a catalyst in operationalising the therapeutic relationship in a physiotherapy context. Continued efforts are needed in physiotherapy education and training in both enhancing theoretical awareness of the role of the therapeutic relationship within physiotherapy practice, as well as guidance on its implementation in clinical practice. (Søndenå , Dalusio-King, & Hebron , 2020)

A clear explanation and expression of support from the physiotherapist can lead to greater trust in patients and understanding of treatment options. This in return can make it easier for the patient to adhere

to recommended therapy, which in turn improves a particular health outcome. Talk about your previous experiences with therapy and what you are currently looking for. Share what is useful, and what is not. Ask questions that will help you feel comfortable working with some new ones. Communicate your needs and wishes during treatment.

METHODOLOGY RESEARCH AND DISCUSSION

During the analysis for the purposes of this work, the description method was used, primary data sources, which are reflected in the author's notes made during the time spent working with interviewed respondents as well as secondary sources. The aim of this paper is based on the overview of the overall aspiration to understand the importance of communication of healthcare workers with a focus on managing the physiotherapist's communication in terms of communication during preparation for training as well as care of sports injuries.

Analysis of the role and importance of physiotherapist's, whose results were presented in this paper, is based on data from the survey. The results presented in this paper are based on the data obtained based on the analysis of the author's research in this area, apropos a review of the situation from 2018-2023. The analysis was used in the research itself to study communication between physiotherapists and Formula 1 drivers as well as communication between physiotherapists and the football team. We included subjects football team players aged 17 to 33 years in the study and Formula Porshe team driver 35-year-old. (Stefan Stojanović, Phys^{2}io, Vienna, Austria)

It is evident that people/spectators do not see many people, doctors, physiotherapists, and others on TV during a Formula 1 or Porsche Cup 911 race working behind the scenes to maintain the physical and mental health of the driver.

The task of the MS Racing physiotherapist-Porsche Team during the race weekends is to have an insight into the condition and form of the drivers. It is necessary to see whether he is sufficiently prepared and focused on training, his diet is taken care of, and that the athlete strictly adheres to the prescribed plan.

The physiotherapist, together with the driver, does the main task of exercises before the qualification itself. The goal of the physiotherapist is that the driver only thinks about driving when he gets in the car and prepares for the day of qualifications. It is necessary to create such a communication atmosphere between them that they perfectly understand each other.

Drivers used to prepare intensively for races, but today it is not possible because otherwise, they would be overloaded. Preparation must therefore take place in advance and on the track, the pilot/driver only needs to go through training to activate the muscles. Sometimes the driver can play a sport, but he has to be very careful to reduce the risk of injury. For example, table tennis is good for improving coordination and reaction speed, as well as neurocognitive training in various forms.

Two days before the race when the driver is in the vehicle for the first time, it is necessary to warm up. After completed driving, he must also take care of rest, followed by fascial therapy, stretching exercises, and reaction training. Fascial therapies are carried out at a low intensity because we do not want to cause pain. Mostly, the affected regions are the neck, shoulders, and sometimes the lumbar spine. Muscles in this area must be flexible because the high G forces stress them and there is a risk of injury. If the driver gets into the car without a warm-up routine, injury could occur, so it must always be ensured that the muscles are always in good condition, warmed up, and flexible.

The driver has very little free time on the route. Because of his duties, the driver must be careful about what and when he eats because he has to have time to digest things. It usually takes 2 to 3 hours. That's why it's being calculated that he has enough time before the session to digest what he has eaten. This

is not always the case, because drivers are under stress due to the schedule and therefore meals that are easily digestible are offered. For the concentration of the driver, it is very important to always follow the same plan. (Stefan Stojanović, Phys²io, Vienna, Austria)

The main task of the physiotherapist is to guide the driver in the right direction. Make sure he adheres to all points of the plan, to receive therapy, to warm up, to drink enough water, and to prepare well as well as to concentrate only on the race.

In the analysis of communication between the physiotherapist and the football team, the physiotherapist for football players, on the one hand, is responsible for the first medical aid for the entire team, and on the other hand, takes care of appropriate therapeutic measures in the regeneration and player injury phase. Physiotherapy does not replace the team doctor, but focuses primarily on physiotherapeutic treatments, which may precede medical measures. (Stefan Stojanović, Phys²io, Vienna, Austria)

In the diagnosis of sports injuries, the physiotherapist is in principle the most important and decisive factor because he is at the scene of the injury. He is mostly present every day in training and in every competition, and he must know how to make valid decisions. Therefore, good communication between the physiotherapist and the injured athlete is of great importance.

The main task of a physiotherapist is to support doctors with health promotion measures before, during, or after medical therapy. A physiotherapist can use different treatment methods such as applications of fascia therapy, movement therapy - manual therapy, or osteopathic procedures as well as various others for the purpose of health and recovery of football players.

Due to the heavy physical effort, injuries to football players during training or during the match cannot be ruled out. There is a significant risk of injury to the entire musculoskeletal system. In the case of symptoms of disease or injury, especially of the muscular, ligamentous, and bony structures, a team doctor and physiotherapist are required. Both initiate medical first aid measures, while the physiotherapist takes care of maintaining or restoring the player's mobility. After the injury, it is the physiotherapist's responsibility to ensure that the player has as little pain as possible through rehabilitation measures to quickly regain the old capacity.

One of the authors Stojanovic S., personally works as a physiotherapist in the Football Club "Team Wiener Linien". "Elektra" together with its team (doctor, athletic trainer, masseur) offers a wide range of treatments that are specially adapted to the needs of football and ensure optimal care, regeneration, and rehabilitation for sports injuries. It should be noted that the physiotherapist in football can rely on a wide range of treatments. With well-grounded knowledge, physiotherapists have various tools available that ensure a quick and individual healing process. A clinical thermometer, a rescue blanket, and a resuscitation bag are part of the basic inventory. Medicines that are on the doping list or require a prescription are not included. Basic medical training guarantees an individual approach to the treatment of an injured athlete. As in individual sports as well as in team sports, the physiotherapist's tasks are to cause as little pain as possible and to quickly return to fitness.

CONCLUSION

It can be concluded that successful management communication in physiotherapy depends primarily on good teamwork, i.e., cooperation between the physiotherapist, the club doctor, and finally the athletes themselves in the specific research of a football player, i.e., formula driver, which is the key to achieving sporting success. Communications style patient-centred the provision of emotional support and allowing patient involvement in the consultation process enhance the therapeutic alliance. The modern way of sports training has reached such a level that the athlete or the driver himself is asked for maximum effort, self-

denial, good mental and health condition. Caring for an injured athlete after the injury will largely depend on the method of treatment, and that's when the club doctor comes to the fore. The physiotherapist is the one who first receives information from the athlete and can convey it to the club doctor, as well as the team coach. That work is so intertwined that you don't need to ask for more importance in the actions of any team member, and only good and joint cooperation can give good results. The results of the interviews showed that good communication between the physiotherapist and the athlete leads to the desired results, otherwise the result will be absent. The conducted research is accompanied by certain limitations arising from the size and structure of the sample. Namely, the research covered only one football team of 11 players (aged 17 to 33 years) and one driver (35-year-old), in the period from 2018 to 2023, which is why the obtained results cannot be generalized. The interview was conducted on a small sample and should be repeated with a new generation of athletes in the next 4 to 5 years.

It is desirable to supplement the data collection techniques with a questionnaire that can be expanded with additional closed and open questions through which more precise and complete information on the quality of communication between the physiotherapist and the athlete would be obtained.

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