Quality of Life

(Banja Luka)

VOLUME **17** ISSUE **1-2** February 2026 ISSN 1986-602X
The Republic of Srpska, Bosnia and Herzegovina EISSN 1986-6038

UDC 614

A Multidisciplinary Journal of Food Science,
Environmental Science and Public Health

APEIRON
ΑΠΕΙΡΟΝ

VOLUME 17
ISSUE **1-2**

Quality of Life
(Banja Luka)

Izdavač/Published by Panevropski univerzitet "Apeiron" Banja Luka/ Pan-European University "Apeiron" Banja Luka
Urednik izdavača/Editor of University Publications Aleksandra Vidović, Bosnia and Herzegovina

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Web design Marko Milovanović
Printed by Markos design & print studio, Banja Luka
Printed in 300 copies

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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:

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- Sewage; Treatment, disposal, utilization of sewage
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- Measures against industrial and other nuisances
- Occupational health hazards; Occupational health and hygiene
- Ecology; Environmental engineering, sustainability and health
- Related topics

UDC 614 Quality of Life is registered with the Ministry of Science and Technology of the Republic of Srpska by serial registration code 07.030-053-160-4/10, date 03.03.2010.
Quality of Life (ISSN 1986-602X) is an international journal published two times a year.

Indexed in:

ebscohost.com
crossref.org
esjindex.org
citefactor.org/contact
road.issn.org
scholar.google.com
cosmosimpactfactor.com
doisrpska.nub.rs
erihplus.nsd.no

UDC 614

ISSN 1986-602X (Print)
ISSN 1986-6038 (Online)

Quality of Life

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Dear readers,

It is a distinct honour to welcome you to this latest issue of *Quality of Life*. As we navigate the complexities and innovations of 2026, we look back with pride on the journey that has brought us here, while firmly focusing on the future of global well-being.

Our mission remains steadfast: to serve as a premier platform for high-quality research across the vital disciplines of **Food Science and Technology, Public Health Engineering, Sanitary Control, and Environmental Health**. In an era where sustainability and precision health are more critical than ever, the papers within this issue reflect the cutting-edge advancements and challenges of our time.

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We wish to extend our heartfelt thanks to:

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We look forward to your future contributions and to another year of advancing the science of living well.

Warm regards,
The Editorial Board *Quality of Life Magazine*

DOI: 10.7251/QOL2601005S **UDC:** 159.913-053.9:575.22.087.1

Original scientific paper

Cognitive Screening in Older Adults: Insights from a Cross-Sectional Study Using Mini-Mental State Examination (MMSE)

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Abstract: Objectives: The study aimed to evaluate cognitive functioning in older adults using the Mini-Mental State Examination (MMSE) in a sample from Bangalore, India. **Method:** A convenience sampling method was used. A total of 71 anonymized MMSE scores were collected through convenience sampling at Bangalore Neurocentre in Bengaluru, India. The sample included 38 males and 33 females. Educational backgrounds varied: 15 participants had an education below Secondary School Leaving Certificate (SSLC), 19 had completed SSLC, and 37 had a degree. The data were subjected to one-way ANOVA and Pearson correlation analysis. **Result:** The study revealed no significant differences in MMSE scores between males and females, but a significant difference in MMSE scores among educational levels, with a medium effect size. Specifically, older adults with an academic background below SSLC scored lower than those with a degree. Additionally, there is a significant difference in the sub-scale of orientation, registration, and language in the MMSE among educational levels, with a medium effect size, in which older adults with an educational background of a degree scored greater than individuals with below SSLC. There is a significant relationship between education and components of MMSE, with a correlation coefficient ranging from a moderate to a strong relationship. Education plays a crucial role in cognitive functions, and individuals with higher education backgrounds tend to perform better in various cognitive domains.

Keywords: Cognitive Functions; Older Adults; Mini-Mental Status Examination; Cross-Sectional Study.

INTRODUCTION

According to the World Health Organization (2023), there are around 10 million new instances of dementia reported each year, and over 55 million people worldwide have been diagnosed with the disease. According to the Longitudinal Ageing Study in India (LASI), impaired cognitive ability was 15% in those 60 years and older and 5.6% in people 45–59 (Pandey et al., 2023). Numerous "clinical tests of the sensorium" that assess cognitive function have been proven valid and reliable by researchers. These tests are lengthy and time-consuming. The "Mini-Mental State Examination" (MMSE), a shortened, scored version of the cognitive mental status test, was developed to address this problem, as it takes five to ten minutes to administer and has eleven components. It helps track the progress of illness, identify cognitive deficits, and monitor how well treatment works. While suggested as a screening tool in 2001, the MMSE should not be the main criterion for diagnosing psychiatric problems, as different circumstances can impair cognitive performance. The patient's history, a thorough mental status assessment, and pertinent laboratory results must all be considered when interpreting the results (Tombaugh & McIntyre, 1992).

MMSE is a well-known way to assess cognitive impairment. This tool is crucial in clinical and research settings because it is easy to administer, well-established, standardized, and effective for monitoring changes over time. It ignores concerns about mood, abnormal mental experiences, and thought patterns in Favor of concentrating on the cognitive components of mental processes. 206 persons with dementia syndromes, emotional disorders, mania, schizophrenia, personality disorders, and 63 healthy individuals, and other conditions have been shown to respond well to the MMSE (Folstein et al., 1974).

The Mini-Mental State Examination (MMSE), as adapted by Kurlowicz and Wallace in 1999, remains one of the most widely used cognitive screening tools in both clinical and research settings. Originally developed by Folstein et al. (1975), the MMSE was designed as a brief but effective instrument to assess cognitive impairment across several domains, including orientation, registration, attention and calculation, recall, and language. Kurlowicz and Wallace's adaptation focused on standardizing administration and improving applicability, specifically among older adults, recognizing the necessity for a practical tool that could be completed quickly yet thoroughly within this population (Kurlowicz & Wallace, 1999). Given that cognitive decline is not an inevitable part of aging but is often linked to underlying pathological or physiological processes, timely assessment via the MMSE allows healthcare providers to detect early changes that may require intervention.

Since its adaptation, extensive research has verified the MMSE's reliability and predictive validity as a screening tool, especially when administered with proper consideration of these demographic and sensory factors. Its widespread acceptance reflects its enduring utility in geriatric nursing and neuropsychological assessment, helping to guide early intervention and management of cognitive decline (Kurlowicz & Wallace, 1999).

The impact of MMSE is significant; for instance, researchers have found that it positively correlates with the Montreal Cognitive Assessment (MoCA), FOTOTEST, resting-state EEG biomarkers, RUDAS, and Saint Louis University. In China, 22.8% of men and 29.5% of women with dysfunction said they had thoughts of killing themselves. Furthermore, MMSE can not only be conducted on older adults but can also be used for children. Nardes et al. (2020) evaluated the reliability of the Mini-Mental State Examination (MMSE) in screening cognitively impaired children with Duchenne muscular dystrophy (DMD). The results showed 78% accuracy and 82% sensitivity in identifying cognitive impairment; besides it also observed a moderate correlation between MMSE and the Wechsler Intelligence Scale for Children. Additionally, Dinomais et al. 2016 and Su et al, 2021 highlighted that physical activity, improved social interaction, nutritional status, and level of education are strong predictors of cognitive function. Moreover, lower MMSE scores are associated with depression, and greater grey matter atrophy indicating cognitive decline, along with increased mortality (Jia et al., 2021; Su et al., 2021; Smith et al., 2022).

Using MMSE scores alone for diagnosis might be inaccurate due to their biases and limitations. Comprehensive evaluations and further tests are necessary for a precise diagnosis (Folstein et al., 1975). Education also affects the MMSE scores. Rijnhart et al. (2023) noted that women had an average MMSE score 0.84 points lower than men, primarily due to fewer years of education. The direct effect was 0.24. This means that equal education could raise women's MMSE scores by this amount. These results have also been proved by a study conducted in China by Xie et al. (2016), which aimed to improve cognitive impairment screening by generating normative MMSE data for illiterate and low-educated populations. The findings suggest that MMSE scores declined, with illiterate females scoring lower than males. A study conducted by Matallana et al. (2011) found that cultural and language factors influence MMSE results, highlighting the memory domain's potential for early cognitive decline detection in less-educated older adults. Meanwhile, Zhu and Zhang (2024) assessed that using the MMSE and other assessments, cognitive dysfunction prevalence at 38.3% in males and 44.6% in females. In China, 22.8% of men and 29.5% of women with dysfunction said they had thoughts of killing themselves. Despite valuable insights from existing research, there is a need for comparative analyses across gender and different educational levels within specific geographical contexts. This study aims to address these gaps by examining the Mini-Mental State Examination as a screening tool for cognitive decline among older adults in Bangalore, thus contributing to a better understanding of the aging population, cultural significance, and demographic disparities in cogni-

tive performance faced by older adults. The study aims to evaluate the cognitive assessment screening tool for cognitive decline among older adults.

METHODOLOGY

The study uses a quantitative methodology with a cross-sectional research design. The data for this study were collected at Bangalore Neuro Centre (BNC), a specialized neuro centre in Bangalore, India. The patients were referred by neurologists for cognitive assessments and were assessed by a trained neuropsychologist, employing standardized procedures to maintain consistency and reliability. The inclusion criteria included individuals belonging to older adults (60 years and above), being right-handed, residing in Bengaluru, and having a neurological evaluation from a neurologist. The exclusion criteria include clients with mental illness and/or neuropsychiatric disorders, epilepsy or any other neurological disorder, severe visual or hearing impairments, illiterates, and individuals unable to understand English and other local languages that could affect their comprehension of or capacity to answer the MMSE questions.

Following initial screening based on inclusion and exclusion criteria, eligible participants were informed about the present study's purpose and procedures. Those who provided written informed consent underwent sociodemographic data collection and were administered the Mini-Mental State Examination (MMSE), adapted by Lenore Kurlowicz, and Meredith Wallace (1999) to assess cognitive functions. The study included anonymized data with their demographic information and corresponding MMSE scores of 71 older adults. All participants were right-handed. Of these, 15 had an educational background below SSLC (Secondary School Leaving Certificate; Below High School), 19 had completed SSLC (High School), and 37 had obtained a degree.

Material

The mini-mental status examination (MMSE) which has been specifically adapted by Lenore Kurlowicz, and Meredith Wallace (1999). It consists of eleven questions scored out of 30 and is intended to evaluate areas including orientation, registration, attention and concentration, memory, language, and visuospatial ability. A score of 23 or lower is indicative of cognitive impairment. The MMSE takes only 5-10 minutes to administer and is therefore practical to use repeatedly and routinely. This questionnaire has been utilized and its validity supported in studies involving Indian populations, as demonstrated by Monroe et al. (2012) and Tiwari et al. (2009).

Statistical Analysis

All statistical analysis was conducted in SPSS 27 (IBM Corp., 2020). Descriptive statistics, including means, standard deviations, and frequencies, were utilised to summarise MMSE scores. One-way ANOVA was used to compare the MMSE scores across different educational levels, and Pearson correlation statistical tests were used to explore the relationships between components of MMSE Scores and Educational levels among 71 older adults.

RESULTS

Table 1 shows that no significant differences in MMSE scores between males and females across various cognitive domains. It also showed no significant differences in orientation, registration, attention, concentration, memory, language, and visuospatial ability scores for males and females. Indicated males and females performed similarly in all measured components, and it does not favour one gender over the other.

Table 1: Shows the mini-mental status examination scores among males and females on descriptives and one-way ANOVA.

Sl. No	Variables	Groups Compared	N	Mean	Std. Deviation	Std. Error	F value	P value
1	Total Score	Male	38	17.32	5.60	0.90	0.01	0.90
		Female	33	17.48	5.70	0.99		
2	Orientation	Male	38	6.24	2.30	0.37	0.004	0.95
		Female	33	6.27	2.24	0.44		
3	Registration	Male	38	2.37	0.81	0.13	0.01	0.90
		Female	33	2.39	1.02	0.17		
4	Attention and Concentration	Male	38	2.00	1.69	0.27	0.49	0.48
		Female	33	2.30	1.94	0.33		
5	Memory	Male	38	0.79	1.01	0.16	0.06	0.79
		Female	33	0.73	1.00	0.17		
6	Language	Male	38	5.74	1.53	0.24	0.07	0.78
		Female	33	5.64	1.47	0.25		
7	Visuospatial Ability	Male	38	0.18	0.39	0.06	0.13	0.71
		Female	33	0.15	0.36	0.06		

Table 2 suggests a significant difference in educational levels among total scores and sub-scales of MMSE, such as orientation, registration, and language, in which older adults with an educational background of a degree scored higher than individuals with below SSLC. Referring to Table 2.2, there is a medium effect size between the pair below SSLC and degree of orientation and registration, along with the pairs below SSLC and SSLC, as well as below SSLC and degree in language, with a moderate effect size.

Table 2.1: Shows the mini-mental status examination scores among education levels on descriptives and one-way ANOVA.

Sl. No	Variables	Groups Compared	N	Mean	Std. Deviation	Std. Error	F value	P value
1	Total Score	Below SSLC	15	14.53	5.11	1.32	3.28	0.04*
		SSLC	19	19.32	2.98	0.68		
		Degree	37	17.57	6.41	1.05		
2	Orientation	Below SSLC	15	5.13	2.74	0.71	3.16	0.04*
		SSLC	19	6.24	2.40	0.40		
		Degree	37	7.16	1.67	0.38		
3	Registration	Below SSLC	15	1.87	1.06	0.27	3.73	0.02*
		SSLC	19	2.43	0.95	0.15		
		Degree	37	2.68	0.47	0.11		
4	Attention and Concentration	Below SSLC	15	2.27	1.79	0.46	0.05	0.94
		SSLC	19	2.08	1.93	0.31		
		Degree	37	2.16	1.64	0.37		
5	Memory	Below SSLC	15	0.47	0.73	0.19	2.33	0.10
		SSLC	19	0.68	0.94	0.15		
		Degree	37	1.16	1.21	0.27		
6	Language	Below SSLC	15	4.80	1.14	0.29	3.64	0.03*
		SSLC	19	5.89	1.69	0.27		
		Degree	37	6	1.05	0.24		
7	Visuospatial Ability	Below SSLC	15	0.00	0.00	0.00	2.31	0.10
		SSLC	19	0.24	0.43	0.07		
		Degree	37	0.16	0.37	0.08		

Table 2.2: Shows the results of the post hoc test for Mini-Mental Status Examination among educational levels on one-way ANOVA.

Sl. No	Variables	Pairwise comparison	Mean Difference	P value	Eta Squared
1	Orientation	Below SSLC and SSLC	-1.11	0.27	0.08
		SSLC and Degree	-0.91	0.35	
		Below SSLC and Degree	-2.02*	0.03*	
2	Registration	Below SSLC and SSLC	-0.56	0.09	0.09
		SSLC and Degree	-0.25	0.57	
		Below SSLC and Degree	-0.81*	0.02*	
3	Attention and Concentration	Below SSLC and SSLC	0.18	0.94	0.00
		SSLC and Degree	0.07	0.98	
		Below SSLC and Degree	0.10	0.98	
4	Memory	Below SSLC and SSLC	-0.20	0.76	0.06
		SSLC and Degree	0.48	0.20	
		Below SSLC and Degree	-0.69	0.11	
5	Language	Below SSLC and SSLC	-1.09*	0.04*	0.09
		SSLC and Degree	0.10	0.96	
		Below SSLC and Degree	-1.20*	0.03*	
6	Visuospatial Ability	Below SSLC and SSLC	-0.24	0.08	0.06
		SSLC and Degree	-0.08	0.69	
		Below SSLC and Degree	-0.15	0.43	

Table 3 reveals that education has a small positive association with language and visuospatial ability, while gender and education have a small negative correlation. Orientation has a strong positive correlation with the total score, indicating a large effect. Other factors such as registration, attention and concentration, memory, and language also show large positive correlations with the total score. Visuospatial ability also has a medium positive correlation with the total score. Orientation is moderately correlated with registration, attention, and concentration, and memory, with a large positive correlation with language and a small positive correlation with visuospatial ability. Registration shows small positive correlations with attention and concentration, visuospatial ability, and memory, but a large positive correlation with language.

Table 3: Shows the results of Pearson's correlation statistics among 71 older adults.

Sl. No	Variables	R-value	p-value
1	Gender - Education	-0.256	0.031
2	Education - Language	0.247	0.038
3	Education - Visuospatial Ability	0.249	0.036
4	Orientation - Total	0.848	0.000
5	Registration - Total	0.649	0.000
6	Attention and Concentration - Total	0.650	0.000
7	Memory - Total	0.505	0.000
8	Language - Total	0.752	0.000
9	Visuospatial Ability - Total	0.447	0.000
10	Orientation - Registration	0.410	0.000
11	Orientation - Attention and Concentration	0.377	0.001
12	Orientation - Memory	0.345	0.003
13	Orientation - Language	0.566	0.000
14	Orientation - Visuospatial Ability	0.283	0.017

15	Registration - Attention and Concentration	0.243	0.041
16	Registration - Memory	0.379	0.001
17	Registration - Language	0.535	0.000
18	Registration - Visuospatial Ability	0.307	0.009

DISCUSSION

The objective of the study is to evaluate the cognitive abilities of older adults through the MMSE scores using a cross-sectional approach, revealing significant insights into cognitive function and its interaction with demographic characteristics. Although this sample did not show significant differences in MMSE scores between males and females, larger multinational research offers a nuanced view. For example, Kistler-Fischbacher et al. (2025) reported that education consistently supports cognitive functioning, but gender effects varied widely across countries. Further investigations into mild cognitive impairment (MCI) reveal noteworthy gender-specific trends in prevalence and risk factors. A study among older adults in China showed women have higher MCI rates than men and experience unique risks related to longer sleep durations and reduced physical activity (Liu et al., 2022). In addition, the progression of cognitive decline is faster in women with MCI, highlighting the critical importance of early, gender-sensitive screening and intervention strategies (Lin et al., 2015).

It was also observed in the current study that there is a moderate to strong effect size difference in the sub-scale of registration in the Mini-Mental State Examination among male and female individuals, where males scored greater than females, which aligns with existing research. A study revealed that women often score lower than men on cognitive tests such as MMSE. These differences could stem from varying influences including biological factors for example, hormonal changes brought on by the drop in estrogen levels during menopause. Because of its neuroprotective properties, estrogen can affect cognitive performance when it is reduced. Women are more likely to have age-related cognitive deterioration since they typically live longer than males; Conditions like anxiety and sadness, which can impair cognitive performance, are more common in women; Cognitive decline may also be influenced by gender differences in social participation, career, life experiences, socio-cultural differences, and educational opportunities, all of which might affect how cognitive abilities change with age across genders. suggesting the need for localized interpretations of gender differences in cognitive aging (Xie et al., 2016; JAMA Network Open, 2020; Sage Journals, 2020; Oxford Academic, 2024; Zhu & Zhang, 2024).

On the other hand, the present study indicate that there is a significant difference in MMSE scores among educational levels, with a medium effect size, in which older adults with an educational background of below SSLC scored less than the individuals with a degree. This aligns with previous research, which highlights that early cognitive decline detection is less common in educated older adults (Matallana et al., 2011). Also, it resonates with wider epidemiological evidence emphasizing education's long-term cognitive benefits. Gender differences were associated with some negative effects on cognitive resilience and literacy pathways, suggesting persistent disparities across populations (Van Hootegem et al., 2023; Hu & Zettler, 2025).

Our analysis shows a significant difference in the sub-scale of orientation, registration, and language in Mini-Mental State Examination among educational levels, with a medium effect size in which older adults with an educational background of a degree scored greater than individuals with below SSLC, which corresponds with existing research (Dinomais et al., 2016, and Su et al, 2021). Orientation emerged as a powerful predictor of overall cognitive health, showing strong positive correlations with total cognitive scores. Shi and Qu (2022) highlight orientation's critical role in early cognitive screening, positioning it as

a foundation for timely interventions. Other cognitive domains—registration, attention, memory, language, and visuospatial skills—also closely correlated with global cognitive ability, reflecting the integrated nature of cognition rather than isolated skill sets. This perspective aligns with meta-analytic work advocating for tailored cognitive training to aid aging individuals (Otero et al., 2022).

The interconnectedness of orientation with other cognitive functions further emphasizes cognition's holistic framework in older adults. Moderate to strong links between orientation and registration, attention, memory, and language suggest that deficits in one domain could signal broader cognitive declines. Research similarly document these cross-domain relationships, reinforcing models that depict cognition as a unified system crucial for real-life functioning. Together, these insights confirm previous research while providing deeper understanding grounded in this population. Educational attainment remains a moderately protective factor in cognitive aging, with orientation and core cognitive domains warranting focus in clinical diagnostics and interventions. Future research should explore the mechanisms driving these associations and develop strategies to enhance cognitive resilience among diverse aging groups (Van Hootegem et al., 2023; Shi & Qu, 2022; Hu & Zettler, 2025; Kadushin et al., 2025; Otero et al., 2022; Kadushin et al., 2025).

As stated in the systematic review, schooling develops cognitive reserve, or the brain's ability to adapt and think of new ways to accomplish tasks. By using this reserve, dementia and cognitive decline may be delayed. Educational activities enhance neuroplasticity, which is the brain's capacity to rearrange itself by creating new neural connections. This maintains cognitive function as we age. Cognitive abilities can be preserved and even enhanced through intellectual pursuits and lifelong learning. In educational settings, social interaction is common and beneficial to cognitive health (Association for Psychological Science, 2020; Frontiers in Human Neuroscience, 2021; SpringerLink, 2009). Millions of people worldwide are affected by dementia, an incurable condition that may be prevented and managed with the use of early cognitive screening. Assessments such as the MMSE have shown a high degree of specificity and sensitivity for diagnosing mild cognitive impairment (MCI), which often develops before dementia. Early detection of cognitive decline allows medical professionals to delay the onset of dementia with therapies (Zhe et al., 2023).

Recent longitudinal investigations broaden this perspective by emphasizing the protective role of social engagement and lifestyle in maintaining cognitive health. Xu et al. (2023) found that active involvement in social activities significantly lowered the risk of developing mild cognitive impairment among older adults, underscoring the potential of lifestyle interventions as valuable complements to educational and biological influences. Supporting this, Nissim et al. (2023), in a large-scale European study, reported that bilingualism and consistent multilingual exposure strengthened cognitive reserve and delayed the onset of dementia symptoms. These findings align with the present study's results, reinforcing the view that education and intellectual stimulation are vital strategies for building resilience against cognitive decline across diverse populations.

Advances in neuroimaging research have also provided important insights into how education interacts with brain function. Dong et al. (2024) revealed that higher levels of education were linked to greater cortical thickness and stronger functional connectivity in regions responsible for memory and attention. This offers neurobiological confirmation of the cognitive reserve hypothesis, highlighting education not just as a socio-behavioral factor but also as a structural safeguard, connecting cognitive performance to measurable brain changes.

Nutrition and diet have likewise emerged as modifiable elements that contribute meaningfully to cognitive resilience. García-Casares et al. (2022) demonstrated that greater adherence to the Mediterranean diet improved cognitive outcomes in older adults, particularly in the domains of memory and orientation—

areas identified by the current study as critical predictors of overall cognition. This evidence strengthens the argument that cognitively supportive lifestyles, encompassing diet, education, and social interactions, play a crucial role in delaying age-related decline and enhancing resilience.

In addition, cardiovascular health represents an equally significant determinant of cognitive outcomes in aging. Chen et al. (2023), drawing from a large community-based cohort, found that vascular risks such as hypertension and diabetes markedly increased the probability of developing mild cognitive impairment, with a stronger impact observed among women. These findings highlight the complex interaction between biological vulnerabilities and lifestyle factors, underscoring the need for integrated prevention strategies that extend beyond education to include proactive vascular health management.

These findings ultimately underscore that cognitive outcomes in aging are shaped by a complex blend of biological, social, and environmental factors. While education bolsters cognitive reserve, gender-specific trajectories in decline demand comprehensive, culturally sensitive approaches. Personalized cognitive assessments acknowledging these demographic variations will be crucial to optimizing early detection and evolving treatment paradigms for older adults. Early cognitive screening can be challenging despite its obvious benefits, such as limited access to screening tools and a lack of knowledge among the public and health care professionals. Increasing access, raising awareness, and incorporating screening into standard treatment are all necessary to address these problems. Early screening leads to better symptom management and general health outcomes because it allows medical professionals to develop specific care plans tailored to the needs of those at risk for dementia. It helps individuals and families make informed decisions that could significantly increase the quality of life for both patients and caregivers (Porsteinsson et al., 2021; Yamasaki & Ikeda, 2024).

CONCLUSION

We have observed that older adults in Bangalore exhibit no significant gender differences in cognitive abilities, as measured by the Mini-Mental State Examination (MMSE). However, those with lower education levels consistently scored lower in areas like orientation, registration, language, and overall cognitive performance. This trend shows a moderate to strong link between educational background and MMSE components**.**

Implications

The findings highlight the value of lifelong learning and fair access to quality education for promoting cognitive health. Early investments in education improve long-term cognitive resilience (Ministry of Human Resource Development, 2020). Health education included in school curricula and adult learning programs can improve mental, physical, and nutritional well-being, which supports cognitive function (National Education Policy, 2020).

Limitations And Future Recommendations

The study's small and unrepresentative sample limits how widely the results can be applied. Future research should include larger and more diverse populations across India. Combining MMSE with other cognitive tools and biomarkers, conducting long-term studies, and using digital platforms can improve screening accuracy and accessibility. Promoting early cognitive screening is still important.

Acknowledgement

The authors are grateful to the participants for their involvement in this research.

Data Availability

The data sets used and/or analysed in this study are available from the corresponding author upon reasonable request.

Conflict Of Interest

The authors report no conflict of interest.

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Recived: September 19, 2025
Accepted: November 15, 2025

DOI: 10.7251/QOL2601015K **UDC:** 316.624:613-057.874

Original scientific paper

Baseline Water, Sanitation and Hygiene (WASH) Survey at Primary Schools in the Republic of Srpska, Bosnia and Herzegovina

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Abstract: Within the goals of the Protocol on Water and Health, Bosnia and Herzegovina (Federation of Bosnia and Herzegovina and Republic of Srpska) has set the goal on improving WASH (Water, Sanitation and Hygiene) in primary schools. The baseline WASH survey at primary schools is planned as the first activity in its achievement. The overarching goal of school-based WASH is to improve sustainability of hygiene, sanitation and water supply services. Such services are a core component of infection prevention and control. The aim of the research is to examine the state of WASH in primary schools in the Republic of Srpska. The research is a cross-sectional epidemiological study conducted from September 2019 to March 2020 in the Republic of Srpska, Bosnia and Herzegovina. Conditions of WASH were assessed in 67 primary schools. The results of a survey showed that all investigated schools provided basic water services, 75.7 % of toilets provided basic sanitary services and 61.2 % of hand washing facilities provided basic hygiene services. The results revealed that there is a need for increased awareness and efforts to ensure basic provisions for sanitation, hygiene and drinking-water safety. Such measures are essential to achieving the Sustainable Development Goals (SDGs) by 2030.

Key words: hygiene, sanitation, schools, water, WASH.

INTRODUCTION

Access to safe water, sanitation, and hygiene (WASH) is a basic human right and primary schools play a critical role in ensuring students' health and holistic welfare (UN General Assembly, 2010). The World Health Organization (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene is responsible for monitoring the Sustainable Development Goal (SDG) through targets 6.1 and 6.2 (WHO & UNICEF, 2023). The goal of school-based WASH is to improve the sustainability of hygiene, sanitation, and water supply services, and promote lifelong health for children and their families (UNICEF, 2011). Improving WASH conditions in schools constitutes a significant catalyst for fostering healthier, better educated, and more sustainable communities. It not only promotes consistent school attendance and academic achievement, but also affords students, particularly adolescent girls, an essential element of privacy (McMichael, 2019). WHO conducted a comprehensive evaluation of both the economic viability of WASH program implementation and its health impact, affirming its efficacy in averting mortality attributed to diarrheal syndrome among a vulnerable demographic of schoolchildren. It has been estimated that 1.4 million deaths could be reduced by WASH interventions (Wolf et al., 2023). The most effective way to ensure safe water supply from a source to a tap is the Water Safety Plan (WSP). In the continuous supply of safe drinking water, the primary objectives of the WSP are to prevent or minimize source contamination, reduce or remove contamination through treatment processes, and prevent contamination during the storage, distribution, and handling of drinking water (WHO, 2017). Washing hands with soap and water (water, soap, and towels), hand dryers, a clean environ-

ment, and proper waste disposal are essential for ensuring good hygiene practices in schools (WHO, 2019). Hand hygiene is one of the most fundamental and effective personal hygiene measures for safeguarding children against infectious diseases (Klar et al., 2022). Facilities must consider the specific needs of girls and women concerning menstrual health and hygiene. Girls are more affected than boys because the lack of sanitary facilities may lead them to refrain from attending school during their menstrual periods (McMichael, 2019). Special needs of children with disabilities must also be considered in facility design plans (UNICEF, 2016). The aim of this study was to assess the current state of WASH facilities in primary schools in the Republic of Srpska, Bosnia, and Herzegovina.

MATERIAL AND METHODS

This research was conducted from September 2019 to March 2020 in the Republic of Srpska. The Republic of Srpska, with 1,142,495 citizens (mid-year estimate for 2019), is one of the two entities in Bosnia and Herzegovina (Republika Srpska Institute of Statistics, 2020). We assessed the conditions of the WASH in 67 of the total number of 203 primary schools. The study sample was identified from the registry of the Republic Pedagogical Institute RS as representative, including urban and rural sites (The Republic Pedagogical Institute of the Republic of Srpska, 2020). All schools included in the research were public, providing education mainly from the first to the ninth grade. In some rural areas, schools only provide education up to fifth grade.

Data collection. For this study, surveillance instruments developed by the WHO and UNICEF to monitor WASH in schools were used (WHO, 2019b). We used two primary instruments for data collection: a survey questionnaire administered to school administration staff and a questionnaire (checklist) focusing on the hygienic and sanitary attributes of individual toilets and handwashing facilities. The questionnaire focused on key WASH issues, including general information on the school, main water sources, functionality and quality, accessibility for youngest children and physical disabilities, handwashing facilities, cleanliness and accessibility of toilets and availability of soap, operation, and maintenance of systems, and disposal waste. The questionnaire consisted of six blocks divided into: general information about the school; water management (17 questions); sanitation (13 questions); hygiene (14 questions); waste disposal (9 questions); and operation and maintenance (10 questions). The instruments were translated into the local language and adapted to best reflect conditions, terminology, and national requirements in the Republic of Srpska. The questionnaire was administered to authorized representatives of the schools during pre-scheduled visits. Face-to-face interviews with school administrators were conducted in their respective offices, with each interview lasting for approximately 45 minutes. A total of 67 questionnaires were successfully completed and 67 school administrators were interviewed. During these site visits, we inspected all sanitary facilities and handwashing facilities while simultaneously completing questionnaires to assess their current state. The collected data were subjected to statistical analysis using IBM SPSS Statistics software (version 22). The analytical procedures included descriptive statistics such as graphical representations, statistical inferences, and dynamic statistics. Categorical data were summarized using frequencies and percentages, whereas numerical variables were represented using standard measures of central tendency, including the mean and standard deviation (SD).

DATA ANALYSIS

The WASH assessment was made using several tools for collecting valid information on water, sanitation, and hygiene services. Questions on drinking water aimed to determine the type of source and availability of the school's main and were based on JMP definitions of "improved" and "unimproved"

sources. These criteria are sufficient to calculate the "basic" water service in schools. Tables 3 and 4 show how the questions in the questionnaire were grouped to calculate the percentage of basic and advanced WASH services (drinking water, sanitation and hygiene) in schools, considering human rights indicators such as accessibility, quality, and safety. Sanitation questions are designed to determine whether schools have restrooms and whether the school's sanitation facilities are usable, functional, and separated by gender. Data were tabulated using the Excel 2019 software for Windows.

Drinking water

The infrastructural provision for water supply was available at all the schools at the time of observation. The most of the visited schools had access to drinking water, provided through an improved source, distributed by the public (municipal or local) water supply system of all schools (95.52 %; 90.56-100 95% CI). Of the total number of visited schools, 3.97% relied on individual water supply systems. **Figure 1** illustrates the type of water supplay in all schoos, as well as by school location (urban vs. rural). The research showed that urban schools predominantly use muncipal water supplay (81.39 % of urban schools), and only one urban school (2.33 %), relied on a protected dug well as its source of drinking water. The water supply in schools is functional throughout the year, and the available water is used for drinking, hand washing, and toilet flushing. According to the survey, approximately 67% of schools were subject to regular drinking water quality monitoring conducted by competent authorities. In contrast, around 33% of schools lacked routine water quality assessments. Rulebook on health and safety of water intended for human consumption (Rulebook on health and safety of water intended for human consumption, 2017), prescribes at least four basic water tests to be conducted during the school year in the water supply facilities at school, with one of these tests taking place 15 days before the start of the school year. **Table 1** presents data on the number and range of drinking water analyses conducted in rural primary schools in the Republic of Srpska during the 2019–2020 period. Microbiological analysis revealed that six out of 163 drinking water samples were contaminated: three samples contained *Escherichia coli*, two had total coliform bacteria, and one exhibited elevated colony counts at 22 °C. Residual chlorine levels were below the recommended reference values in two samples, while four samples showed increased turbidity. Elevated iron concentrations were identified in one sample.

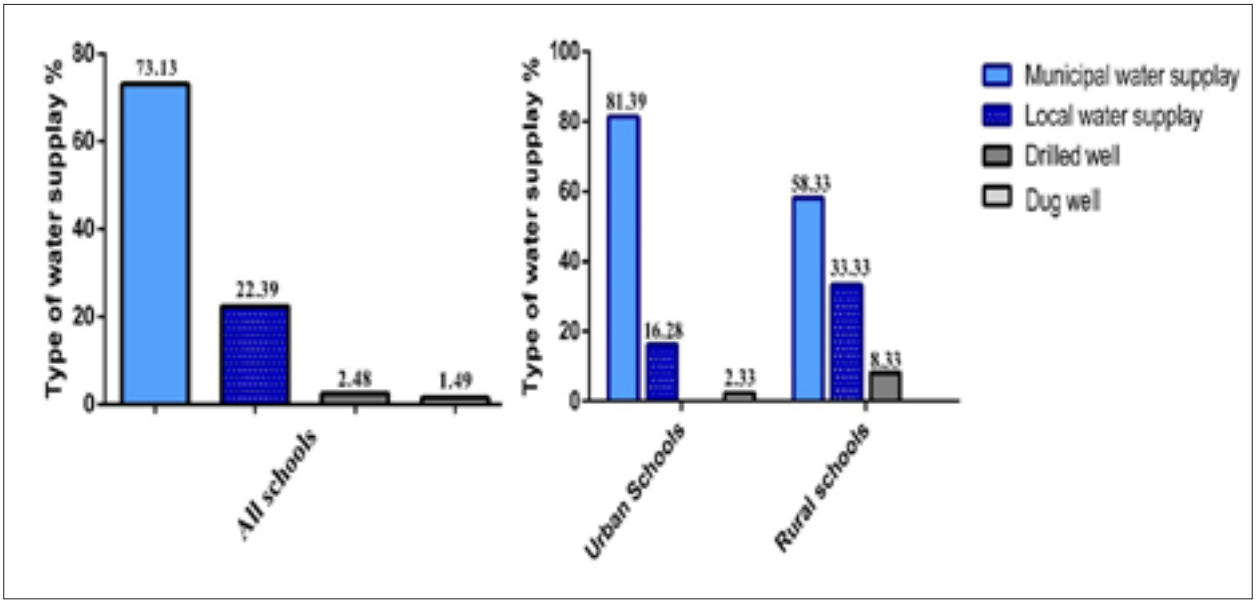


Figure 1. The type of water supply in school of Republic of Srpska (RS)

Table 1. The results of drinking water quality analyses in schools (2019-2020.)

Region	Microbiological analysis			Physical-chemical analysis		
	Schools N	Analyses N	Not in accordance N (%)	Schools N	Analyses N	Not in accordance N (%)
Banja Luka	11	101	5 (4.95)	11	101	7 (6.93)
Zvornik	5	26	0	5	26	0
Trebinje	3	9	1 (11.10)	3	10	2 (20.0)
I.Sarajevo	5	27	0	5	27	0
All samples	**24**	**163**	**6 (3.68)**	**24**	**164**	**9 (5.49)**

Sanitation

All of the assessed schools had sanitation facilities, however only 28 schools (41.79 %) had toilet facilities completely separated by gender, 46.51 % of urban schools, and 33.33 % of rural school. Additionaly, in the Republic of Srpska 16 schools used shared toilet (23.88 %) (18.61 of urban schools, and 33.33 of rural schools **(Table 2).** The data from survey reveals that, on average, 33.84 students share one toilet (39.84 girls share one toilet, while 29.53 boys use one toilet or one urinal, respectively) **Figure 2**. An evaluation of compliance with WHO guidelines (Grossi, Klimschak, Rechenburg, Shinee & Schmoll, 2016) regarding the number of students per toilet, the following observations were made: in accordance with WHO recommendations, only 27.9% of urban schools meet the required standards. Furthermore, 58% of urban schools fail to comply with these recommendations, while 14% of urban schools meet requirements for boys only. Additionally, 75% of rural schools fulfill the required standards **(Figure 3).**

Table 2. Distribution of Toilet Facilities by Gender Separation in schools in RS

Toilets facilities	All Schools (N=67)		Urban Schools (N=43)		Rural Schools (N=24)	
	N	% (95% CI)	N	% (95 % CI)	N	% (95 % CI)
Completely separated by gender	28	41.79 (29.95-53-63)	20	46.51(30.92-62.10)	8	33.33 (14.48-52.18)
Partially separated by gender	23	34.33 (22.96-45.70)	15	34.88 (20.08-49.68)	8	33.33 (14.48-52.18)
Only shared toilets	16	23.88 (13.67-34.09)	8	18.61 (6.44-30.76)	8	33.33 (14.48-52.18)

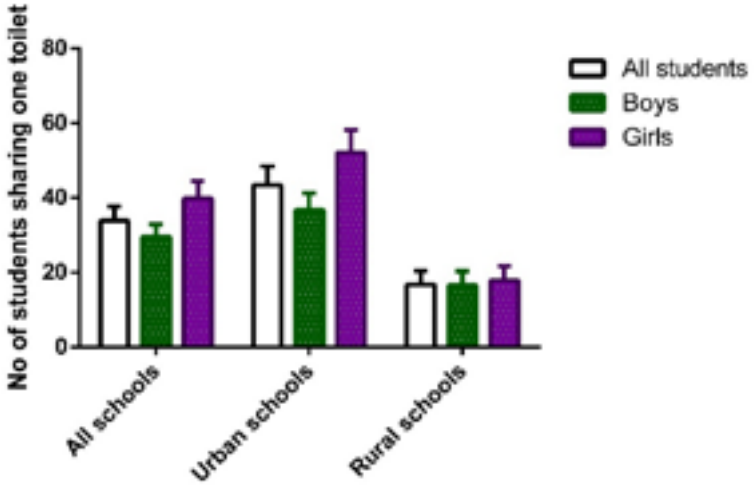
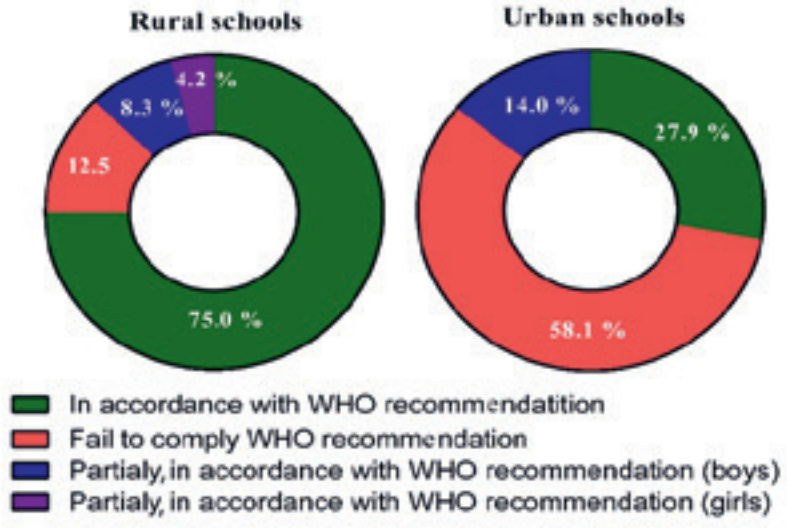


Figure 2. Number of students sharing one toilet in the schools in the Republic of Srpska.

Data are presented as Mea n ±SE

Figure 3. Distribution of urban and rural schools according to compliance with WHO recommendations on the number of toilets for male and female students



In all 67 schools included in the survey, an inspection of on-site toilets was carried out. **Notably,** 98.9 % of urban and 98.1 % of rural toilet cubicles were clean. Also**, signs of vandalism were rare,** affecting only 7.4 % of urban toilets and none in rural settings (6.2% overall). **Gender separation** was significantly more common in urban schools (79.7%) than in rural schools (55.6%). **Access for persons with disabilities** remained low in all schools (7.7% overall) underscoring a significant gap in the infrastructure needed to support inclusive education. Moreover, the results showed that a substantial proportion of toilet cubicles lacked toilet paper (45.5% of all schools). Additionally, all schools had notable deficiencies in waste disposal: 72.3% did not provide trash bins inside each cubicle**. Table 3** presents the number and percentage of toilets exhibiting selected characteristics. Regarding sanitary wastewater disposal, 55.2% schools have central wastewater disposal (74.41% of urban school and 20.83 % rural school), 44.8% of schools are connected to a septic tank. Additionally, 92.4% of schools have a management and maintenance plan in place. In terms of waste management practices, 78.8% of schools had centralized waste disposal, while 37.9% had centralized waste removal.

Table 3. Number and percentage of toilets with selected sanitation facilities in urban and rural schools

Questions	Urban schools Number of toilets N (%)		Rural schools N (%) Number of toilets N (%)		All schools Number of toilets N (%)	
	Present	Absent	Present	Absent	Present	Absent
Toilets with signs of vandalism	20 (7.4)	251 (92.6)	0 (0.0)	54 (100.0)	20 (6.2)	305 (93.8)
Gender-separated toilets	216 (79.7)	55 (20.3)	30 (55.6)	24 (44.4)	246 (75.7)	79 (24.3)*
Clean toilet cubicles	268 (98.9)	3 (1.1)	53 (98.1)	1 (1.9)	321 (98.7)	4 (1.2)
Toilet paper	148 (54.6)	123 (45.4)	29 (53.7)	25 (46.3)	177 (54.5)	148 (45.5)
Trash bins in the toilet area	206 (76.0)	65 (24.0)	38 (70.4)	16 (29.6)	244 (75.1)	81 (24.9)
Trash bins in each toilet cubicle	70 (25.8)	201 (74.2)	20 (37.0)	34 (63.0)	90 (27.7)	235 (72.3)
Accessibility for persons with disability	23 (8.5)	248 (91.5)	2 (3.7)	52 (96.3)	25 (7.7)	271 (83.4)

Data are presented as N (%).χ 2 Chi-Square test:* $p < 0.001$.

Hygiene

During the research in schools in Republic of Srpska, it was found that WASH infrastructures were available in schools, but menstrual management facilities in schools are neglected. Results show that 62.1% (n=41) of all schools provide education on menstrual hygiene, while 27.3% (n=18) do not include menstrual education in the curriculum, and 10.6% (n=7) did not provide response. Schools that reported lacking education on menstrual hygiene are predominantly in rural areas. They mentioned that their students are of a younger age group, as they only provide education up to the fifth grade. Within the school curriculum, 86.5% (n=58) of educational institutions offered education on the importance of handwashing. All toilets were in the building and have pipe water available at all time when children felt the need to use them. Figure 4 illustrates number of students sharing one tap in the schools of Republic of Srpska.

The results revealed several deficiencies, including the lack of soap, towels, and hot water availability. Notably, only 93 toilets (28.4 %) had hot water availability **Table 4**.

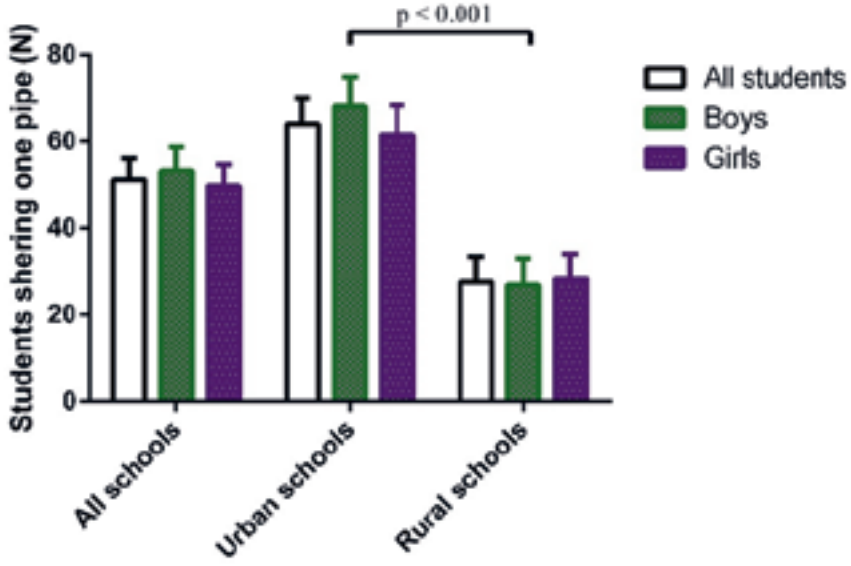


Figure 4. Number of students sharing one tap in the schools of Republic of Srpska

Table 4 . Number and percentage of toilets with selected hygiene facilities in urban and rural schools

Questions	Urban schools Number of toilets N (%)		Rural schools N (%) Number of toilets N (%)		All schools Number of toilets N (%)	
	Present	Absent	Present	Absent	Present	Absent
Water availability 24/7	274 (100)	0 (0.0)	53 (100)	0 (0.0)	327 (100)	0 (0.0)
Hand dryers / towels	165 (60.2)	109 (39.8)	28 (52.8)	25 (47.2)	193 (59.0)	134 (41.0)
Soap availability	166 (60.6)	108 (39.4)	34 (64.2)	19 (35.8)	200 (61.2)	127 (38.8)
Good hygiene	269 (98.2)	5 (1.8)	53 (100)	0 (0.0)	322 (98.5)	5 (1.5)
Hot water availability	87 (31.8)	187 (68.2)	6 (11.3)	47 (88.7)	93 (28.4)	234 (71.6)*

Data are presented as N (%).χ 2 Chi-Square test:* $p < 0.01$.

DISCUSSION

This research was conducted to examine the state of WASH in primary schools in the Republic of Srpska. The results indicated that WASH infrastructure was generally available in schools; however, several important areas require improvement, including the lack of toilets for younger students, the absence

of facilities for students with disabilities, and the insufficient provision of menstrual hygiene management facilities. The study revealed that 3.97% of the schools visited relied on individual water supply systems. It is noteworthy to contrast these findings with those from Croatia, where only 0.63% of the schools were not connected to the public water supply system (Capak et al., 2015). To achieve Sustainable Development Goal (SDG) 6 – clean water and sanitation – service providers should prioritise efforts towards schools and communities that depend on individual or local water supply systems. A total of 22.39% of schools relied on local water supply systems. The primary issue stems from the use of local water supply sources, which are more susceptible to breakdown and contamination than larger utility systems. The assessment and expansion of access to sustainable, lasting water and sanitation infrastructure remains a global health challenge (Bolatova et al., 2021). Waterborne diseases are a significant global health concern. Diarrhoeal diseases, primarily stemming from water contamination and inadequate sanitation, result in 829 000 WASH-attributable deaths annually and contibute to over 49.8 million Disability Adjusted Life Years (DALY's) (Prüss-Ustün et al., 2019). In the Republic of Srpska, during the research period (2019–2020), no officially registered waterborne diseases were reported, based on collected, processed, and publicly available data (PHI RS 2019, 2020).

One of the issues we found concerning sanitation facilities was absence of facilities for pupils with disabilities. The pupils with disabilities receive primary education in regular schools through inclusive practice and their unique needs must be carefully considered in facility design plans. Only 25 toilets (7.7%) were adapted for students with disabilities, highlighting a substantial shortfall in infrastructure for inclusive education. Globally, more than a billion people live with some form of disability, with nearly 240 million of them being children (Long & Guo, 2023).

During the research in schools in Republic of Srpska we found that menstrual management facilities in schools are neglected. Several previous studies have also shown that menstrual hygiene management facilities in schools have been neglected in low- and middle-income countries (McMichael, 2019., Shrestha et al., 2022, Poague et al., 2022). Gender equality issues often arise when girls reach puberty, as menstruation remains a taboo subject in many cultures, leading to stigma and shame among girls (Baird et al., 2022). Adolescent girls and women in most countries have access to materials and a private place to wash and change, but often don't participate in school, work and social activities during menstruation (Wolf et al. 2023). Education on menstrual hygiene management is essential for primary school-aged girls. According to the data obtained in the research published by Jovanović and colleagues in 2022, it is evident that 50% of schools in the surveyed rural schools in Serbia lack menstrual hygiene education, and that in 79% of schools there is a lack of appropriate facilities for the disposal of menstrual hygiene products (Jovanović, Karadžić, Paunović, Ranković & Vasić, 2022). Most girls experience their first menstruation during the age of 10–14 years old which is school going age. A survey conducted among students in Nepal, revealed that out of 126 participants, 106 reported taking days off during menstruation in the past three months, with an average of 2.6 days per student (Shrestha et al. 2022). In 2012, WHO/UNICEF Joint Monitoring Programme for Drinking Water, Sanitation, and Hygiene defined menstrual hygiene management as „women and adolescent girls using a clean menstrual management material that can be changed in privacy as often as necessary, using soap and water for washing the body as required, and having access to facilities to dispose of used menstrual management materials" (UNICEF, 2019). The study of WASH in schools was also conducted during the COVID-19 pandemic by Pague and colleagues through a systematic review of peer-reviewed literature, encompassing 65 studies that covered 18,465 schools across 30 different developing countries, and the results indicate a lack of adequate WASH conditions in all countries (Pagou et al., 2022). The COVID-19 pandemic serves as a significant reminder that hand hygiene constitutes a fundamental cor-

nerstone for effective infection prevention. Reports indicate that appropriate hand hygiene can reduce the incidence of diarrhea by as much as 33% and respiratory infections, including common cold and influenza, by up to 20% (Xun et al., 2021). School age is seen as the most favorable age for the adoption of positive habits (Khan, Ashraf, Iftikhar & Baig-Ansari, 2021). Insufficient and inadequate school infrastructure hinders students from practicing healthy hygiene habits, particularly handwashing (Pagou et al. 2022). Improving access to sanitation not only addresses needs, but also enhances safety, dignity, and self-esteem in the school environment (Hutton & Chase, 2017). In 2020, approximately 1.7 billion people lacked access to fundamental sanitary facilities such as toilets equipped with sinks or squat toilets. Substantial disparities persist, with the most disadvantaged populations, particularly those residing in rural areas, having the lowest utilization of basic sanitation services. Worldwide, 494 million individuals still resort to open defecation because they lack access to toilet facilities. The prevalence of open defecation is most pronounced in sub-Saharan Africa, Central and South Asia, and Oceania, as reported by the World Health Organization (Mothiba, Khabo-Mmekoa, Ngobeni-Nyambi & Momba, 2023).

CONCLUSION

Our study reveals that while WASH infrastructure is generally available in most schools in the Republic of Srpska, there are notable areas requiring improvement. Schools relying on local water supply systems or independent facilities face potential health risks. Our research underscores that children with disabilities face significant barriers in accessing appropriate toilet facilities, and girls encounter inadequate menstrual hygiene management. Addressing these deficiencies is crucial for advancing Sustainable Development Goals, particularly Goal 10 (reducing inequality) and Goal 4 (achieving gender equality). Effective solutions require collaboration between public health initiatives and local communities to foster a supportive and inclusive school environment that meets the diverse needs of all students.

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Recived: October 20, 2025
Accepted: November 5, 2025

DOI: 10.7251/QOL2601024V **UDC:** 616.98:579.841]-084(497.6)
Original scientific paper

Influence of Air Conditioning Devices Age, Distribution Installation Materials, Maintenance and Dynamics of Use on the Appearance of *Legionella*: A Study Conducted in the Territory of the Federation of Bosnia and Herzegovina

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Abstract: Because man strives to ensure the comfort in living and working spaces, there is a lot of air conditioning devices to achieve the desired temperature. Bacteria from the genus *Legionella* is a pathogenic bacterium that can cause the disease to occur in very severe form. It most often inhabits water systems created by human activity, among which are air conditioning devices, which is why there is a need to test factors that favors bacteria colonization. The study included 79 facilities from the territory of the Federation of Bosnia and Herzegovina, of which 42 or 53.2% facilities with centralized, and 37 or 46.8% facilities with individual air conditioning devices. Data were collected using a survey and laboratory analysis of samples. The analysis was performed individually, taking into account the different requirements and complexity of the two types of air conditioning devices. The objectives were related to the correlation between the age, distribution installation material, project, the maintenance dynamics and the need to use the air conditioner with *Legionella* spp. colonization. The results indicate a positive influence of the air conditioner age and steel distribution installation on the *Legionella* spp. colonization. Significant correlation was not observed between the collected survey responses (project, maintenance and the air conditioner use frequency) and the *Legionella* spp. colonization. The identification of factors that positively correlate with the presence of *Legionella* spp. in air conditioning devices has significant public health and technical contribution, especially in the context of legionellosis prevention, the implementation of adequate monitoring and maintenance.

Keywords: Legionellosis, monitoring, public health contribution, technical contribution, Water systems.

INTRODUCTION

In recent decades, global warming and climate change have contributed that people for acheiving the necessary temperature parameters inside closed spaces use air conditioning, and create comfort with an artificial climate. Based on previous reports (Hernandez-Martin et al., 2025, Liu et al., 2024, Grassie et al., 2025), there is a justified indication for installing air conditioning devices. However, attention should also be paid to the risks posed by conditioned air, since the colonization of bacteria from the genus *Legionella* (*L*. spp.) has been established in air conditioning devices (Elsanousi, R. M. A. & Elsanousi, S. M. 2017, Gea-Izquierdo, et al., 2023, Yao et al., 2024). It is a well-known fact that *L*. spp. is the cause of a disease called legionellosis (Obradović, 2013). In general, the trend shows an increase in the number of people suffering from legionellosis in many European countries and the mortality rate is high (Barskey, et al. 2022, European centre for disease prevention and control, 2024). People with weakened immunity and existing comorbidities are most often affected, and a lethal outcome often occur. The disease can occur in all age groups, including children, but it most often affects middle-aged and elderly people (Kalenić , et al., 2013).

It has been proven that the disease occurs three times more often in men than in women (Dautović-Krkić & Čengić, 2010). In facilities with increased mobility of people and the air is contaminated, the disease spreads very quickly through aerosols (Seppänen & Fisk, 2004). From the aspect of unfavorable influence of conditioned air, in addition to *legionella*, other Gram-negative bacteria and viruses can threaten human health. Contamination of ventilation openings and air conditioning devices with various microorganisms often occurs (Apte et al., 2004). Air conditioning devices based on refrigerant (most often freon) so-called individual air conditioning devices are used where strict control of temperature and humidity in the air-conditioned space is not required, when the investor is limited by financial means, the deadline for installing the device, and when there is space limitation (Selection Of Air Conditioning Systems, 2024). Centralized air conditioning devices represent an air conditioning plant, made up of several interconnected components, which are used to condition the air. The demanding technical performance makes them much more complex compared to individual air conditioning devices (Nyers, 2016). Centralized air conditioning devices are most often installed in larger facilities, such as hotels, hospitals and larger office buildings. They are used for economic reasons and to achieve optimal quality of conditioned air (2002 report of the refrigeration, air conditioning and heat pumps technical options committee (RTOC), 2023), and facilities that operate seasonally are at greater risk of *L*. spp. colonization (Obradović, 2013). These air conditioning devices most often use water for their operation (Selection of Air Conditioning Systems, 2024), and it is known that water is the most suitable medium for the occurrence and proliferation of *L*. spp. (Ontario Agency for Health Protection and Promotion, 2019). The materials of distribution ducts are often made of steel or galvanized steel (Todorović, 2005), while recently, plastic pipes have also been installed more frequently (Nyers, 2016). The materials must meet many criteria, including durability, flexibility, easy cleaning and smooth internal surfaces (Todorović, 2005). An integral part of a good project are the parts of the installed equipment. It is also necessary to take into account the size of the facility and its purpose for which it is necessary to ensure certain microclimatic conditions, while not neglecting environmental awareness (Kaladzija, 2024). It is the responsibility of the designer to ensure that the volume of dead space is reduced within the design of all water supply and air-conditioning devices due to the accumulation and stagnation of sediment, as such conditions, especially in biofilm, are conducive to the development of *L*. spp. (Ghernaout et al., 2022). Cooling towers are often used to change the water temperature and remove excess heat (Kaladzija, 2024). Stagnation and circulation of water, as well as occasional use of the device, certainly have a beneficial effect on the colonization of bacteria in the cooling tower (*Legionella* – treating the critical risks in cooling towers: Section 8, 2024). Defective and old parts of the tower, as well as damaged ones, are conducive to the formation of biofilm, and servicing is a preventive measure when it comes to contamination by various microorganisms (Legionnaires' Disease Outbreaks, are Cooling Towers High Risk?, 2024). In the Federation of Bosnia and Herzegovina, there is no single regulation dedicated exclusively to *L.* spp. in relation to air-conditioning. Prevention of *L*. spp. colonization in air-conditioning devices is regulated through a combination of health, technical and sanitary regulations (Law on the Protection of the Population from Infectious Diseases, 2005, Rulebook on technical properties of ventilation and air conditioning systems, 2009, Rulebook on technical properties of heating and cooling systems, 2009). The existing regulatory framework indicates the need for additional research into the real risks and the level of compliance with the prescribed hygiene and technical standards in practice.

The objectives of the research are:

To examine the relationship between the age of the air conditioning devices and the *L*. spp. colonization,

To examine the relation between the materials of the distribution installation of the air conditioning devices and the *L*. spp. colonization,

To determine the impact of the project and the dynamics of servicing the air conditioning devices with the *L*. spp. colonization,

To establish the connection between the dynamics of the use of the air conditioning device and the *L.* spp. colonization.

MATERIAL AND METHODS

The research was conducted at the territory of the Federation of Bosnia and Herzegovina, Bosnia and Herzegovina (2023 – 2024). The survey covered 79 buildings. The condition for inclusion in this study was that they were public and larger facilities. Smaller facilities and facilities that people rarely visit are not included in the research. Out of total, 42, or 53.2%, of buildings with centralized air-conditioning devices and 37, or 46.8% of buildings with individual air-conditioning devices are covered. In all investigated facilities, sampling (N=173) was carried out from previously defined critical places of the air conditioning device, based on professional and scientific literature (water cooling tower and water tank, condensed water, filters, diffusers and turbines). The number of samples per facility ranged from 1 to 8, and the air conditioning device was considered contaminated if *L*. spp. was isolated in only one sample. Sampling was performed using the wet swab method using a sterile stick (BAS EN ISO 18593:2019) and by pouring water from the outlet that circulates through the air conditioning system (BAS EN ISO 19458:2008). The samples were taken within the stipulated time transported to the agreed laboratory in Sarajevo, which is in the process of accreditation according to the requirements of the BAS EN ISO 17025:2018 standard. All the collected samples were cultured, due to the low number of bacteria, and membrane filtered 11731-2:2018. Furthermore, a structured interview was conducted in each of the investigated facilities using a paper-based questionnaire in charge of air conditioning maintenance, managers or deputies of the investigated facilities. The questionnaire used is exclusively the author's work, and was created on the basis of a review of numerous professional and scientific literature, recommendations from authorized air conditioning service providers, and on the basis of previous competence and expected evidence in practice. The questionnaire consisted of seven questions. The questions were of a closed type, three of which offered a YES/NO answer.

Statistical methods

The results are presented in tables and/or charts by absolute number and percentage. The chi-square test was used to test the differences of discrete variables. The results of the mentioned test are considered statistically significant at the confidence level of 95%, or with a value of $p < 0.05$. The analysis was performed using the statistical package IBM Statistics SPSS v 25.0 (Chicago, Illinois, USA).

RESULTS

In Table 1. are presented the collected responses to the survey question regarding the age of the air conditioner device. The analysis was performed based on the classification according to the type of air conditioner device, the findings on *L*. spp. and the survey responses. According to the presented data, an increased frequency of *L*. spp. colonization was observed in older air conditioning devices. The result of the statistical analysis using the chi-square test shows that there is a statistically significant difference ($p<0.05$) in favor of a higher prevalence of *L*. spp. colonization in air conditioning devices which are more than ten years old.

Table 1. Relationship between the age of the air conditioning device and the colonization with L. spp. (N = 79)

Survey question and answers collected in the facilities			Type of air conditioning device				Total
			Centralized		Individual		
			L. spp.		L. spp.		
			Not detected	Detected	Not detected	Detected	
Age of the air conditioning device	Up to 5 years	N	7	0	18	0	25
		%	100.0	0.0	100.0	0.0	31,6
	From 6 to 10 years	N	13	3	10	0	26
		%	81.3	18.8	100.0	0.0	32,9
	More than 10 years	N	11	8	7	2	28
		%	57.9	42.1	77.8	22.2	35,4
Total		N	31	11	35	2	79
		%	73,8	26.2	94.6	5.4	100.0

χ^2=15.899, p=0.005, L. spp. - bacteria from the genus Legionella;

The collected answers to the survey question related to the material of the distribution installation of the air conditioning device are shown. The analysis was done on the basis of the classification according to the type of air conditioning device, the obtained findings on *L*. spp., and survey responses. It is evident that regardless of the materials of the distribution installation, the possibility of colonization with *L*. spp. is not excluded, but the result of statistical analysis using the chi-square test shows that there is a statistically significant difference ($p<0.05$) in favor of a positive correlation of steel distribution installation with the appearance of *L*. spp. in air conditioning systems (Table 2).

Table 2. Correlation of the distribution installation material of the air conditioning devices with the settlement of *L.* spp. (N = 79)

Survey question and answers collected in the facilities			*L.* spp.		Total
			Not detected	Detected	
Distribution installation of the air conditioning device (material type)	Galvanized	N	23	1	24
		%	95.8	4.2	
	Steel	N	8	10	18
		%	44.4	55.6	
	Plastic	N	35	2	37
		%	94.6	5.4	
Total		N	66	13	79
		%	83,5	16.5	100.0

χ^2=25.939, p=0.0001, *L.* spp. - bacteria from the genus Legionella

Table 3 shows the collected survey responses related to the design and servicing of centralized air conditioning devices. The analysis was performed based on the obtained findings on *L*. spp. and survey responses. Although the air conditioning devices were installed according to the design, signed by an authorized person, and have the appropriate documentation and a contract with an authorized service, it was observed that the colonization of *L*. spp. is not excluded. The obtained data show that *L*. spp. less frequently colonized air conditioning devices when servicing is performed several times a year. However, the results of the statistical analysis using the chi-square test show that there is no statistically significant difference ($p>0.05$).

Table 3. Relationship between the design and maintenance of air conditioning devices and the colonization of L. spp. – centralized air conditioning devices (N = 42)

Survey question and answers collected in the facilities			*L.* spp.		Total
			Not detected	Detected	
The project was signed by an authorized person	Yes	N	31	11	42
		%	73.8	26.2	100,0
Having the necessary documentation	Yes	N	31	11	42
		%	73.8	26.2	100,0
Service frequency χ^2=2.439, p=0.295	Once a year	N	18	8	26
		%	69.2	30.8	61,9
	Twice a year	N	10	1	11
		%	90.9	9.1	26,2
	As needed	N	3	2	5
		%	60.0	40.0	11,9
Having a contract with an authorized service χ^2=0.417, p=0.687	No	N	1	0	1
		%	100.0	0.0	2,4
	Yes	N	30	11	41
		%	73.2	26.8	97,6
Total		N	31	11	42
		%	73,8	26.2	100.0

L. spp. - bacteria from the genus Legionella.

Survey responses related to the design and servicing of individual air conditioning devices were collected. The analysis was conducted based on the findings obtained on *L*. spp. and survey responses. *L*. spp. is more often colonized in air conditioning devices that are installed without a project signed by an authorized person, and if the facility does not have the necessary documentation regarding the air conditioning device. Colonization with *L*. spp. was not observed in air conditioning devices that are serviced at least once a year. However, the results of statistical analysis using the chi-square test show that there is no statistically significant difference (p>0.05) (Table 4).

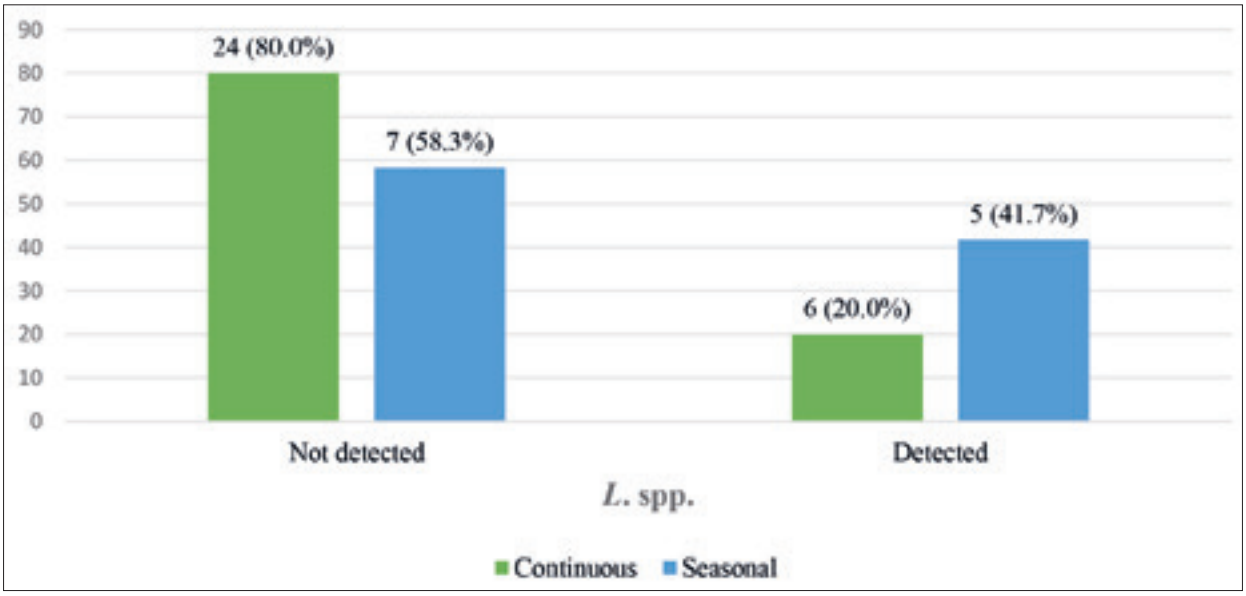
Table 4. Association of air conditioning device design and maintenance with colonization of *L.* spp. – individual air conditioning devices (N = 37)

Survey question and answers collected in the facilities			*L.* spp.		Total
			Not detected	Detected	
The project was signed by an authorized person χ^2 = 0,680; p = 0,410	No	N	26	2	28
		%	92.9	7.1	75,7
	Yes	N	9	0	9
		%	100.0	0.0	24,3
Having the necessary documentation χ^2 = 0,680; p = 0,410	No	N	26	2	28
		%	92.9	7.1	75,7
	Yes	N	9	0	9
		%	100.0	0.0	24,3
Service frequency χ^2 = 2,232; p = 0,328	Once a year	N	6	0	6
		%	100.0	0.0	16,1
	Twice a year	N	13	0	13
		%	100.0	0.0	35,1
	As needed	N	16	2	18
		%	88.9	11.1	48,6

Having a contract with an authorized service $\chi^2 = 0,566$; p = 0,452	No	N	9	1	10
		%	90.0	10.0	27,0
	Yes	N	26	1	27
		%	96.3	3.7	73,0
Total		N	35	2	37
		%	94,6	5,4	

L. spp. - bacteria from the genus Legionella.

Chart 1. Distribution of facilities according to the dynamics of air conditioning use and the connection with the colonization of L. spp. – centralized air conditioning devices (N = 42)



χ^2=2.082, p=0.243, *L* spp. - bacteria from the genus *Legionella*

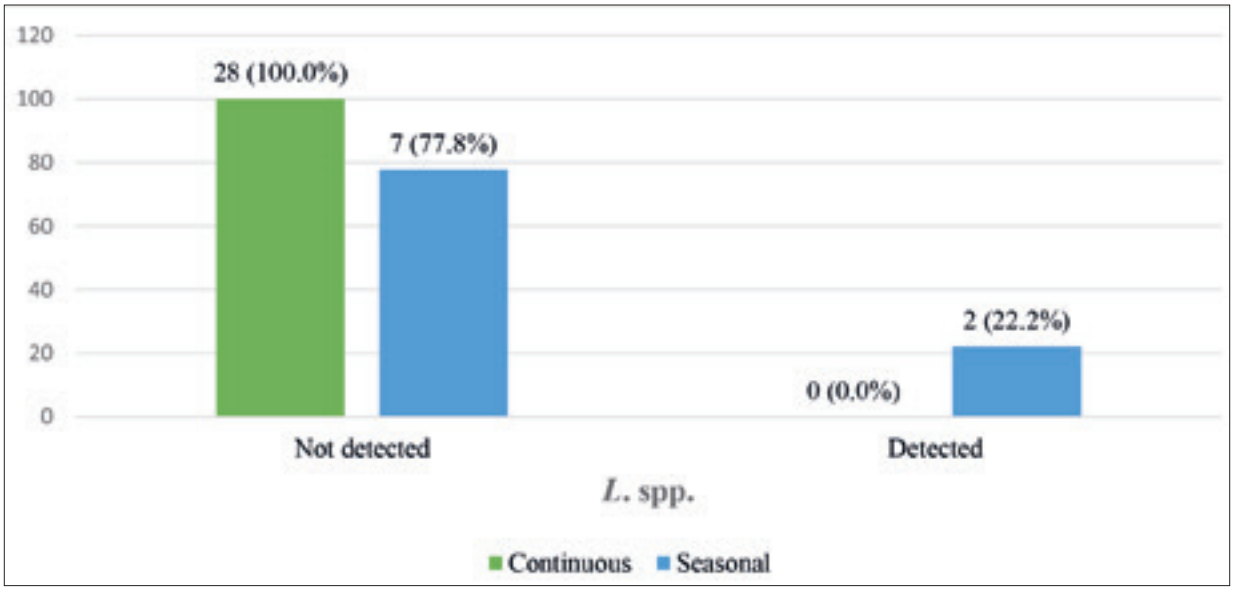
Chart 1. shows the collected survey responses related to the need to use centralized air conditioning devices. The analysis was conducted based on the obtained findings on *L*. spp. and survey responses. The obtained data indicate the possibility of colonization with *L*. spp. in both categories of investigated facilities, but the result of statistical analysis using the chi-square test shows that there is no statistically significant difference (p>0.05).

The collected survey responses related to the need to use individual air conditioning devices are presented. The analysis was performed based on the obtained findings on *L*. spp. and survey responses. The colonization with *L*. spp. was not present in air conditioning devices that are used continuously, with the result of the statistical analysis using the chi-square test showing that there is no statistically significant difference (p>0.05) (Chart 2).

DISCUSSION

The focus of this research, in accordance with the set goals, was to expand knowledge about the factors that influence the *L*. spp. colonization in air conditioning devices. Previously the relationship between the physical and chemical parameters of water in air-conditioning devices and the *L*. spp. colonization was examined, where the results showed that there is a connection between higher temperature and lower concentration of residual chlorine, and higher concentrations of iron and copper, with the *L*. spp. colonization in air-conditioning

Chart 2. Distribution of buildings according to the dynamics of air conditioning use and the connection with the colonization of L. spp. – individual air conditioning devices (N = 37)



$\chi 2 = 6{,}578$; $p = 0{,}054$; *L.* spp. - bacteria from the genus *Legionella*

devices (Vukotić et al., 2025). Our research included two categories of air conditioning devices, which were analyzed separately due to different requirements and complexity. Results showed a correlation between the age of the air conditioning devices and *L.* spp. colonization in both groups of investigated air conditioning devices ($p<0.05$). The results of a study conducted in the Split-Dalmatia County, where hot water from the water supply system was tested for the presence of *L.* spp., also indicate a correlation between the age of the system and bacteria colonization (*Rakić*, 2014). It is characteristic of an older plumbing installation that if the bacterium survives the water treatment in very small numbers, growth and reproduction will continue as soon as it acquires favorable conditions (Barna, et al., 2016). In contrast, the first case of Legionnaires' disease in Bosnia and Herzegovina occurred towards the end of the 1980s, and the source of the infection was an air conditioning device in a newly built hotel, which indicates the possibility of colonization by *L.* spp. regardless of the device age *(Legionella* is nothing new and there is no threat of an epidemic, 2024). Regarding the materials of the distribution installation, our results showed the correlation between the steel distribution installation with the *L.* spp. colonization of the air conditioning unit ($p<0.05$). Based on the results of research in the area of Split-Dalmatia County, a higher concentration of *L.* spp. was found in water samples from galvanized distribution installations compared to plastic ones. The explanation given is that on the smooth inner surfaces of plastic pipes there is less possibility of biofilm attachment and greater possibility of mechanical tearing due to increased water flow (Rakić, 2014). Different interactions with the environment affect the deterioration of material properties, which is especially true for most metals. Metals have the ability to return to their original oxidized state and this process is inevitable (Shaw & Kelly, 2006). Increased concentrations of oxidants and appropriate water flow reduce the concentration of iron released from corroded pipes (Sarin et al., 2004). Water supply systems use water in a temperature range that is favorable for the proliferation of *L.* spp. During operation, aerosols are produced, and in addition, water often stand still and corrosive deposits are present, phenomena that favorably affect the growth and reproduction of *L.* spp. (Martin et al., 2020). Lack of water flow allows the deposition of sludge, from which bacteria draw nutrients. Sludge also contributes to the occurrence of corrosion. Furthermore, all this leads to inhibition of biocides and they cannot reach all parts of the water system in the appropriate concentration (*Legionella* risks – identification and analysis: Section 6., 2024). By analyzing several available sources, it was found that the importance of the design and project of the distribution installation, professional installation, maintenance and regular servic-

ing of air conditioning devices is indicated in order to avoid the risks of the appearance of *L*. spp. and other contaminants, as well as other consequences caused by neglecting the above (Ghernaout et al., 2022, Principle of operation of air conditioners, 2024, López-Gómez et al., 2012, 10 most common malfunctions of air conditioners, 2024). The results of our research on these issues and the connection with the settlement of *L*. spp. did not show statistically significant differences ($p>0.05$), which refers to both categories of investigated air conditioning devices. It is evident that the colonization of bacteria is not excluded, and that the *L*. spp. colonization is more frequent in facilities where air conditioning devices are serviced less often. Preventing the formation of biofilm in the distribution network of water systems is an important measure when it comes to the proliferation of *L*. spp. The connection of biofilm with installation projects has been established, due to redundant pipelines and blind corners. Also, a bad design leads to still water and poor flow, which disrupts the necessary water temperature regime (Ontario Agency for Health Protection and Promotion, 2019). It is considered that individual air conditioning devices do not pose a risk in terms of colonization with *L*. spp. (We've busted the *Legionella* myth: No, the air conditioning in your home won't transmit the dangerous bacteria to you, but something else might, 2025). Although our results showed a low prevalence of facilities in which *L*. spp. colonize an individual air conditioning device, the possibility is not excluded. It is evident in older devices and devices that are less frequently serviced. Irregular maintenance and servicing of certain components of the device can cause the formation of a watery environment in the indoor unit (Air Conditioning. The complete guide for home owners, 2024). It is common for ice to form on the evaporator of the indoor unit. Possible reasons for this are lack of gas, dirty filters or fan turbine (10 most common malfunctions of air conditioners, 2024). A relative humidity of 60% has a positive effect on the survival of this bacterium (Legionnaires' disease outbreak investigation toolbox, 2024). During servicing, replacement or cleaning of air conditioning device filters is a mandatory part of the process. Filter materials of air conditioning devices as well as low humidity reduce the risk of microbial contamination (Ventilation system hygiene. A review of published information on the occurrence and effects of contamination, 2024). By analyzing samples from car air filters for *L*. spp., the findings showed that *L*. ph. was isolated in a third of the samples (Alexandropoulou et al., 2013). When it comes to centralized air conditioning systems, HEPA filters have been used in practice for many years. This type of filter is easily damaged, so it is necessary to pay attention when installing it and to check and change it often. It is important that they are firmly placed in the housing to avoid the risk of leaking unfiltered air into the room (Anil, 2008). In addition, it is necessary to continuously invest in the education of all persons who are in any way connected with the air conditioning processes, primarily in connection with the issue of implementing the correct practice of device maintenance and an increased level of knowledge about the consequences of the occurrence of *L*. spp. (Acquaye, et al., 2020). Regarding the need to use an air conditioning device, our results did not show a statistically significant difference between the two groups of facilities and the type of air conditioning device ($p > 0.05$), which was also confirmed by the results of the research in the Split-Dalmatia County. Based on the conclusions of the mentioned research, the concentration of bacteria in samples from facilities that work seasonally is much higher than in the other group of samples (Rakić, 2014). During the coronavirus (COVID-19) pandemic, tourist facilities in Federation of Bosnia and Herzegovina were closed for a long period of time. Before reopening, and in relation with the issue of *L*. spp., the Ministry of Health of the Federation of Bosnia and Herzegovina and the Institute of Public Health of the Federation of Bosnia and Herzegovina issued guidelines to all responsible persons in order to minimize the risks of legionella infection in such facilities. Some of the operational tasks should have been performed before the actual opening of the facility, accompanied by an educated person from the area. Mechanical cleaning, hyperthermia and hyperchlorination of all risky places and places that are subject to the formation of scale, sediment or biofilm are recommended before opening the facility (Basic guidelines for managers of hotels and other accommodation units on actions to be taken before reopening facilities in order to reduce the risk of infection with bacteria of the

genus *L.* spp. during the COVID-19 pandemic, 2021). By analyzing the regulations of some European countries regarding air conditioning devices and the prevention of *L.* spp. colonization, it seems that in Germany the most clearly defined regulations, guidelines and recommendations are based on which air conditioning devices and the *L*. spp. colonization. Recommendations of the Federal Office for Environmental Protection (Verein Deutscher Ingenieure, 2018). When it comes to the limitation of this research, it can be taken into consideration the reliability of the data collected using the survey questionnaire, which depended on the honesty of the respondents in the facility and the correct understandingof the questions asked. In addition, there was no verification that hygienic measures were applied in practice, nor were the detection of biofilms and dead pipes was included as a project task. Based on the evidence so far, factors for the survival of *L.* spp. which are very important. In accordance with the set goals of the research, the lack of investigation of these factors can represent a significant limitation and affect the reliability of the obtained results.

CONCLUSION

Based on the analysis of the collected survey data and laboratory findings, as well as the summarized results of this research, it is possible to interpret the data in accordance with statistically significant differences. Regarding the age and material of the distribution installation of the air conditioning device, positive correlations were established with the *L*. spp. colonization. Statistically significant differences exist in the group of air conditioning devices older than 10 years, and steel distribution installations, which indicates that the age of the device and the material of the air conditioning installation positively correlates with the colonization with *L*. spp. Regardless of the distribution of the examined air conditioning devices, in terms of design, maintenance and dynamics of use, the results of this study did not show statistically significant differences. It is evident that bacteria colonize the air conditioning device, regardless of the design or maintenance dynamics, although it is less likely if the device is serviced several times during the year. Furthermore, regarding the dynamics of the use of the air conditioning device, the bacteria colonization was not established in the group of buildings where the device is used continuously, and only when it comes to individual air conditioning devices. From a public health perspective, the results of the research enable the identification of risk factors for *L*. spp. colonization in air conditioning devices, which contributes to the prevention of legionellosis and the protection of the health of all facility users. Furthermore, the presented results from the technical aspect can be useful because they indicate the importance of regular and adequate maintenance of the air conditioning devices, and based on which it is possible to improve the maintenance practice and contribute to greater safety and efficiency of the system. Recommendations refer to the modernization of older devices or damaged components, continuous monitoring program of air conditioning devices, regular and documented servicing and staff training. In addition, it would be desirable to continue the research on a larger sample of objects with additional objectives, for the sake of a more complete understanding of the factors that positively influence the *L*.spp. colonization in air conditioning devices.

Funding
No funding was received for this study.

Conflict of Interest
„The authors declare that they have no conflict of interest“

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Recived: November 5, 2025
Accepted: November 8, 2025

DOI: 10.7251/QOL2601035M **UDC:** 613.956-055.15:159.922.7

Original scientific paper

Assessment and Modeling of Environmental Noise From Open-Air Concerts in a Student Residential Area

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Abstract: This paper presents the results of a comprehensive study on the assessment of environmental noise levels at selected locations used for public events in the city of Banja Luka. The research was conducted with the aim of evaluating the impact of noise on the environment and public health, as well as determining compliance of the measured noise levels with applicable legal regulations and the recommendations of the European Union and the World Health Organization. The study includes a theoretical analysis of the physical and physiological characteristics of sound and noise, their propagation in space, perception, and effects on the human organism, as well as a review of the relevant legislative framework. Field measurements were carried out at several representative locations using standardized measuring equipment and prescribed methodologies, and the obtained results were analyzed and graphically presented through noise propagation models. Based on the results, conflict areas with elevated noise levels were identified, and specific urban planning, technical, and organizational measures for noise reduction were proposed. The noise modelling results enabled the definition of a noise protection zone and a maximum permissible sound emission level of 78.5 dB(A) for open-air concert organization in the studied student residential area. The conclusions of the study provide a professional basis for the development of decisions and action plans aimed at sustainable noise management during public events and the improvement of quality of life in the urban environment.

Keywords: noise, modeling, visualization, residental area.

INTRODUCTION

Continuous technological development, urban expansion, and intensification of human activities have led to an increasing degradation of environmental quality, particularly in densely populated urban areas (Barboza et al., 2008; Gašić et al., 2010; Ilić, 2015; Ilić et al., 2018a, 2018b, 2018c, 2019a, 2020a, 2020b; Wang et al., 2020; Ilić and Maksimović, 2021; Zhanibekov et al., 2022; Radović et al., 2022; Ćirišan et al., 2023; Popović and Ilić, 2023a, 2023b). As urban systems evolve, the pressure on environmental components intensifies, resulting in complex forms of pollution that directly affect human health and living conditions. While air and water pollution have traditionally been the focus of environmental protection efforts, environmental noise has emerged as one of the most widespread and persistent stressors in modern cities.

Urban environments are characterized by a constant presence of unwanted sound originating from transportation systems, commercial activities, construction works, and various social and cultural events. These sound emissions, when exceeding acceptable thresholds, are classified as environmental noise and represent a significant disturbance to everyday life (Ilić et al., 2012; Luković et al., 2018; Ilić et al., 2018a, 2018b; Fino, 2019; Ilić et al., 2019a, 2019b; Farooqi et al., 2023). The expansion of cities and the increasing concentration of population have led to a reduction of acoustically protected spaces, while zones intended for residence, education, and recreation are increasingly exposed to elevated noise levels.

Environmental noise is recognized as a major public health concern, with the World Health Organization identifying it as one of the leading environmental risks to human health, second only to air pollution (WHO, 2018). Numerous studies have demonstrated its association with adverse health outcomes, including sleep disturbance, cardiovascular diseases, cognitive impairment, stress-related disorders, and reduced quality of life (Basner et al., 2014, Mohamed et al., 2021). Unlike many other pollutants, noise exerts both immediate and long-term effects, influencing not only physiological responses but also psychological well-being and social functioning. The presence of sounds originating from both outdoor and indoor environments inevitably affects health, learning abilities, and students' academic performance (Ali et al., 2023). In student populations, prolonged and repeated exposure to elevated noise levels has been linked to increased stress, reduced concentration, and lower academic performance, particularly during nighttime periods (Buchari and Matondang, 2017; Zhang et al., 2019).

In urban settings, noise pollution is not solely associated with traffic and industrial activities. Recreational and cultural events, particularly open-air concerts and public manifestations, represent an increasingly important source of high-intensity noise. Such events are typically intermittent but can generate sound pressure levels significantly exceeding background noise, especially in acoustically sensitive zones such as residential areas, student campuses, and educational institutions. Previous research has addressed urban noise mapping, prediction, and management, providing methodologies for assessing spatial distribution of noise and identifying critical exposure zones (Ilić et al., 2021e; Božić et al., 2020; Božić et al., 2018). Studies conducted in the city of Banja Luka have highlighted traffic noise as a dominant source, but have also pointed to the growing importance of event-related noise in specific locations (Ilić et al., 2012, 2017, 2018c, 2018e, 2018f; Janjuš et al., 2015a, 2015b). While previous local studies in Banja Luka have primarily focused on mapping and assessing urban traffic-related noise, they have rarely addressed intermittent, high-intensity event-related noise in acoustically sensitive student residential settings. In contrast, this study targets open-air concert scenarios within a Zone III student campus environment by coupling baseline day/night field measurements with forward-looking acoustic propagation modelling. This approach enables scenario-based optimization of stage placement and orientation and provides operational outputs for event management, including the delineation of a noise protection zone and definition of a maximum permissible emission level for compliant concert organization.

Student residential areas represent a particularly sensitive category within the urban acoustic environment. The presence of large numbers of young people, combined with the need for rest, study, and social activities, creates a complex acoustic context in which both low background noise and controlled social events are expected. Excessive noise exposure in such environments may lead to sleep disturbances, reduced academic performance, increased stress levels, and long-term health effects (Farooqi et al., 2000, 2021, 2022; Popović and Ilić, 2023a). Therefore, careful planning and regulation of noise-generating activities in student zones are essential.

The Student Center "Nikola Tesla" in Banja Luka (Bosnia and Herzegovina) represents a typical multifunctional urban space, combining student accommodation, educational facilities, green areas, and public spaces frequently used for social and cultural events. Due to its location within a residential and educational zone, the organization of open-air concerts at this site requires a detailed assessment of environmental noise impact. Determining appropriate locations for sound sources, defining noise protection zones, and establishing maximum permissible sound levels are crucial steps in ensuring compliance with regulatory requirements and protecting the surrounding population.

Modern approaches to noise management emphasize the integration of field measurements with acoustic modeling and spatial visualization. Noise mapping and predictive modeling enable the assessment

of different scenarios, allowing planners to evaluate the impact of sound source positioning, orientation, and intensity before events take place (Popović et al., 2024b). Such tools are particularly valuable in urban environments, where complex interactions between sound sources, buildings, terrain, and population distribution influence noise propagation.

The aim of this study is to assess environmental noise levels at the Student Center "Nikola Tesla" during daytime and nighttime periods in order to establish the existing baseline acoustic conditions, and to evaluate the suitability of the location for organizing open-air concerts. Special emphasis is placed on defining the optimal position of the sound source and determining the maximum allowable noise levels that ensure compliance with national regulations while minimizing adverse impacts on students and nearby residents. By combining in situ measurements with acoustic modeling and noise mapping, this work contributes to the development of scientifically grounded guidelines for sustainable management of event-related noise in sensitive urban environments.

MATERIALS AND METHOD

Location

The Student Center "Nikola Tesla" is located in an urban area of Banja Luka characterized by a combination of student accommodation facilities, educational buildings, and accompanying public spaces. The location is situated in a densely populated zone with frequent daily human activity, particularly during academic periods. Surrounding land use includes residential buildings, internal traffic routes, pedestrian zones, and green areas, which makes this location sensitive to increased noise levels, especially during the organization of public events. Due to its function and spatial context, the area represents a typical urban environment where noise impact can directly affect a large number of users, primarily students and nearby residents.

According to national noise zoning, the Student Center "Nikola Tesla" is classified as Zone III, which includes pure residential areas, educational and health institutions, and public green and recreational spaces. This classification implies stricter noise limits due to the sensitivity of the population, particularly students and residents. Noise was measured both during the day and at night at six representative measurement points (MT1–MT6) (Figure 1 and Figure 2). The six measurement locations (MT1–MT6) were selected to ensure representative coverage of the study area, taking into account differences in land use, proximity to dominant noise sources, building density, and spatial distribution of student residential facilities. This configuration enabled the capture of both background urban noise conditions and areas potentially exposed to increased sound levels during open-air concert events.

Figure 1. Measurement setup at location MT2 during daytime noise monitoring at the Student Center "Nikola Tesla", showing the sound level meter positioned at a height of 1.5 m above ground level."

Figure 2. Layout of measurement points (MT1–MT6) at the Student Center "Nikola Tesla", marked on the map with white balloons and corresponding location labels.

The model used for assessment of noise level

The assessment of noise levels was carried out using an acoustic propagation model based on standardized calculation methods for outdoor sound propagation in urban environments. The model takes into account the characteristics of the noise source, spatial configuration of the area, terrain morphology, presence of surrounding buildings, and distance between the source and receptor points. Sound attenuation due to geometric divergence, atmospheric absorption, ground effects, and shielding by obstacles was included, allowing for a realistic estimation of noise distribution and identification of zones with elevated noise exposure (Popović et al., 2024a).

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 on Limit Values of Noise Intensity, 2023). 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 T 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 (Popović et al., 2024a).

RESULTS AND DISCUSSION

Noise measurements

Noise measurements were conducted at six representative measurement points (MT1–MT6), strategically distributed across the location to capture spatial variability in noise exposure (Table 1).

Table 1. Measured noise values at the location Student Center "Nikola Tesla"

Measurment point	Coordinates of measuring points	L_{eq} day	L_{eq} night	L_1 day	L_1 night	L_{10} day	L_{10} night
MT 1	44°45'55.24"N 17°12'4.51"E	57,7	46,1	90,4	66,9	79,2	63,9
MT 2	44°45'56.88"N 17°12'0.64"E	56,8	55,6	88,1	77,1	83,1	75,6
MT 3	44°46'0.74"N 17°12'2.18"E	54,2	51,2	81,8	69,4	76,5	67,5
MT 4	44°45'59.87"N 17°11'58.27"E	67,9	69,5	91,2	83,6	85,5	79,4
MT 5	44°45'57.90"N 17°11'53.14"E	50,0	55,6	88,8	79,7	80,2	77,5
MT 6	44°46'2.02"N 17°11'51.56"E	55,0	50,2	76,2	71,3	71,2	66,9

Daytime noise levels

During daytime measurements, the equivalent noise level (Leq) varied significantly across the location. Measurement points MT3, MT5, and MT6 recorded Leq values within the permissible daytime limit of 55 dB(A), indicating acceptable acoustic conditions in these areas.

However, at MT1, MT2, and MT4, measured Leq values ranged from 56.8 to 67.9 dB(A), exceeding the regulatory limit. The highest daytime Leq value was recorded at MT4, which is directly influenced by road traffic in Majke Jugovića Street. This confirms traffic as the dominant noise source during the daytime period.

Peak noise indicators further emphasize the acoustic burden:

- L1 (daytime) values ranged from 76.2 to 91.2 dB(A), exceeding the allowed limit of 70 dB(A) at all measurement points.
- L10 (daytime) values ranged from 71.2 to 85.5 dB(A), also exceeding the permitted value of 65 dB(A).

These elevated peak levels indicate frequent short-term noise events, typical of traffic flow, acceleration, braking, and occasional impulsive sounds, which significantly reduce acoustic comfort even where equivalent levels are marginally acceptable.

Nighttime noise levels

Nighttime measurements reveal a more critical situation. The equivalent noise level (Leq) during the night exceeded the permissible limit of 45 dB(A) at all measurement points, with values ranging from 46.1 to 69.5 dB(A). The highest nighttime Leq was again recorded at MT4, confirming persistent traffic influence even during night hours.

Peak noise indicators during nighttime further confirm excessive noise exposure:

- L1 (night) values ranged from 66.9 to 83.6 dB(A), exceeding the limit of 70 dB(A) at several points.
- L10 (night) values ranged from 63.9 to 79.4 dB(A), with most values exceeding the allowed 65 dB(A).

Given the function of the area as a student residential zone, these nighttime exceedances are particularly concerning, as they may contribute to sleep disturbance, reduced recovery, and long-term health effects.

The spatial distribution of measured equivalent noise levels (Leq) across all measurement points, in relation to the prescribed daytime and nighttime limits, is presented in Figure 3.

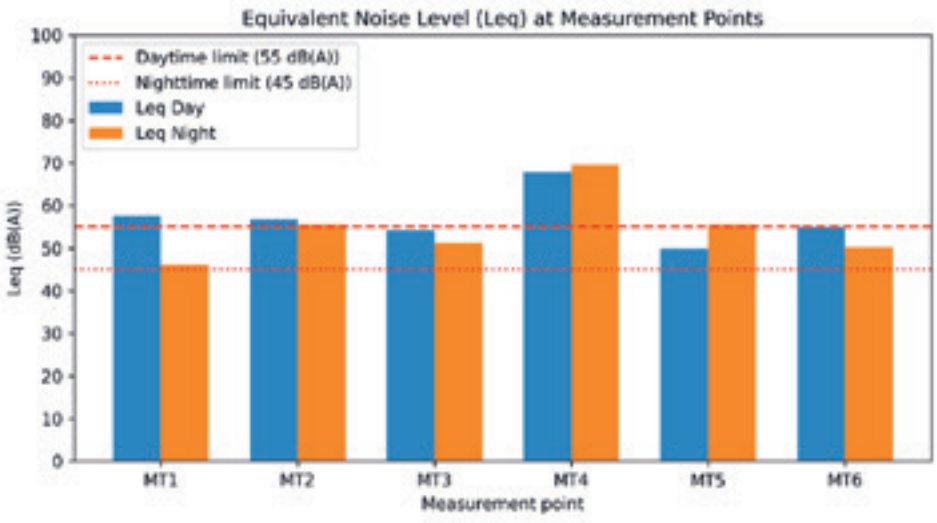

Figure 3. Equivalent noise levels (Leq) measured at MT1–MT6 during daytime and nighttime at the Student Center "Nikola Tesla". Red horizontal lines indicate the legally prescribed limit values for environmental noise: a dashed line represents the daytime limit of 55 dB(A), while a dotted line represents the nighttime limit of 45 dB(A).

Traffic influence on noise levels

Traffic counting conducted at measurement point MT4 shows that road traffic is the dominant noise source at the location. Fifteen-minute traffic counts during both daytime and nighttime periods indicate that passenger cars constitute the majority of vehicles, with increased traffic intensity observed immediately after the start of the nighttime regulatory period (Table 2).

The persistence of relatively high nighttime traffic volumes explains the elevated nighttime noise levels and the limited reduction in Leq values compared to daytime measurements. This confirms that traffic noise represents a continuous pressure rather than an occasional disturbance at this location.

Table 2. Number of vehicles at the location Student Center "Nikola Tesla" during noise measurements

Measurement point	Motorcycles	Passenger cars	Vans	Busses	Vehicles >5t	Total
Daytime measurements						
MT1	-	3	-	-	-	3
MT2	-	-	-	-	-	0
MT3	-	-	-	-	-	0
MT4	15	378	24	-	-	417
MT5	-	-	-	-	-	0
MT6	-	-	-	-	-	0
Nighttime measurements						
MT1	-	-	-	-	-	0
MT2	-	-	-	-	-	0
MT3	-	-	-	-	-	0
MT4	-	132	3	-	-	135
MT5	-	-	-	-	-	0
MT6	-	-	-	-	-	0

Noise propagation and proposed sound source position

The proposed position of the sound source (stage) for public events is located at coordinates 44°45'57.07"N, 17°11'50.04"E. Acoustic modeling of sound propagation from this position shows that, under controlled orientation and sound power conditions, it is possible to maintain compliance with regulatory limits.

Specifically, the model indicates that:

- At the most exposed residential building (Control Point 1), the noise level does not exceed 50 dB(A), in accordance with the applicable regulation.
- Within the defined noise protection zone (marked by the red contour line), the maximum permissible noise level must not exceed 78.5 dB(A).

The noise map (Figure 3) clearly illustrates the directional propagation of the sound field, with contour lines connecting points of equal noise levels. This confirms that appropriate orientation of the sound system and strict control of emission levels are essential for minimizing environmental impact.

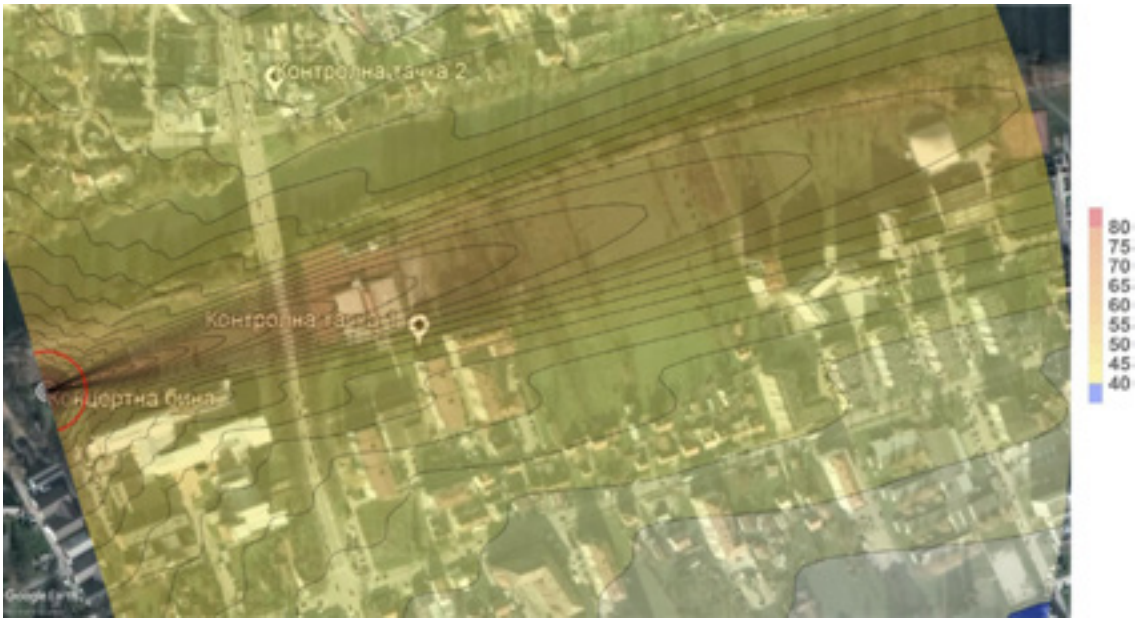

Figure 4. Direction and propagation of the sound front from the proposed stage location at the location Student Center "Nikola Tesla". Points on the map with the same noise level are connected by contours, and the values in the legend are given in dB

The obtained results are consistent with findings from previous studies conducted in university campus environments, which emphasize the importance of integrating field noise measurements with spatial and model-based approaches to adequately characterize noise exposure patterns. Studies combining in situ measurements and noise mapping have shown that such an approach enables the identification of spatial variability and localized areas of elevated noise levels within campus settings, providing a more comprehensive understanding of environmental noise distribution than measurements alone (Zannin et al., 2013). Similarly, propagation-model-based campus noise mapping has been demonstrated to be an effective tool for analysing different exposure scenarios and supporting spatial planning and management decisions in complex university environments (Huang et al., 2022). In this context, the results of the present study further confirm the applicability of measurement-supported modelling as a robust framework for assessing noise conditions in sensitive student residential areas.

CONCLUSION

This study provides a comprehensive assessment of environmental noise conditions at the Student Center "Nikola Tesla" in Banja Luka, with a particular focus on the suitability of the location for organizing open-air concerts in a sensitive urban and student residential environment. The combination of systematic field measurements and acoustic modeling enabled a detailed analysis of both existing background noise conditions and potential impacts associated with event-related sound emissions.

The results clearly indicate that the investigated area is already exposed to elevated noise levels, primarily due to road traffic, even in the absence of public events. Daytime exceedances of equivalent noise levels (Leq) were recorded at several measurement points, while nighttime measurements revealed widespread and consistent exceedances across the entire location. These findings confirm that traffic noise represents a continuous and dominant source of environmental noise pressure in the study area, significantly limiting the available acoustic capacity for additional noise-generating activities.

Peak noise indicators (L1 and L10) further emphasize the acoustic vulnerability of the location, showing frequent short-term noise events that exceed regulatory limits during both daytime and nighttime

periods. Such noise characteristics are particularly critical in student residential zones, where uninterrupted rest, recovery, and favorable conditions for learning are essential. Persistent exposure to elevated noise levels may contribute to sleep disturbances, increased stress, reduced academic performance, and long-term health effects among students and nearby residents.

Despite these constraints, the applied acoustic propagation model demonstrated that, under carefully controlled conditions, the organization of open-air concerts at the Student Center "Nikola Tesla" can be managed in compliance with national noise regulations. The modeling results confirmed that appropriate positioning of the sound source, controlled orientation of the sound system, and strict limitation of sound power levels are key factors in minimizing noise propagation toward the most exposed residential buildings. The defined noise protection zone and the established maximum permissible noise level of 78.5 dB(A) within this zone provide clear operational boundaries for event planning.

The study highlights the importance of integrating measurement-based assessments with predictive noise modeling when planning public events in acoustically sensitive urban areas. Such an approach allows decision-makers to evaluate different scenarios in advance, identify potential risks, and implement preventive measures before regulatory exceedances occur. This is particularly relevant for multifunctional urban spaces, where residential, educational, and recreational functions coexist.

In a broader context, the findings underline the necessity of proactive noise management strategies in student residential zones. Urban planning and event organization should not rely solely on post-event monitoring, but rather on scientifically grounded planning tools that balance social and cultural activities with the protection of public health and quality of life. The methodology applied in this study offers a practical and transferable framework that can be used for similar locations in other urban environments.

Overall, this research confirms that sustainable management of event-related environmental noise is achievable through a combination of accurate field measurements, advanced modeling techniques, and strict adherence to regulatory requirements. By defining optimal sound source locations and maximum allowable noise levels, it is possible to support cultural and social activities while preserving the acoustic comfort and well-being of student populations and surrounding communities.

Conflict of Interest
The authors declare no conflict of interest.

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Recived: December 17, 2025
Accepted: January 14, 2026

DOI: 10.7251/QOL2601046S **UDC:** 546.97+546.94]:547.587.51
Original scientific paper

Assessment of Chemical Hazards in Hospital Workplaces during the Summer Period

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Abstract: Workplace exposure to gaseous chemical pollutants represents a significant occupational health concern in healthcare environments, particularly in large clinical centers where diverse chemical agents are used and emitted. In this study, we provide a comprehensive assessment of chemical hazards in selected workplaces at the Public University Clinical Center of the Republic of Srpska in Banja Luka during the summer period. The results indicate pervasive exceedances of regulatory reference values for acrolein (C_3H_4O) and localized exceedances for nitrogen dioxide (NO_2), suggesting potential occupational relevance in specific areas. Exploratory factor analysis identified six components explaining approximately 79% of the total variance, indicating multiple partially overlapping emission sources. Correlation analysis revealed structured associations among several reactive and aromatic pollutants, pointing to common controlling processes. Differences between operating rooms and other areas were statistically significant for CO_2, CH_4, isopropanol (C_3H_8O), and acetone ($(CH_3)_2CO$). The findings highlight the spatial heterogeneity and activity-driven nature of chemical exposure in hospital environments and support the need for integrated monitoring approaches to improve occupational health risk management. The study contributes to a better understanding of chemical exposure patterns in hospital environments and provides a basis for future risk management and occupational health interventions.

Keywords: Workplace air quality; FTIR gas analysis; hospital environment; chemical exposure; PCA; occupational health; volatile organic compounds; indoor air pollution.

INTRODUCTION

Air quality at workplaces represents a central occupational-health concern because inhalation exposure provides a direct pathway for both acute and long-term health effects. In work environments characterized by the simultaneous use of multiple chemical products, airborne exposure is rarely limited to a single substance. Instead, workers are typically exposed to complex mixtures whose composition and intensity depend on specific activities, ventilation performance, and temporal dynamics. As highlighted in recent exposure-assessment research, short-term concentration peaks may contribute disproportionately to overall health risk, even when longer-term average concentrations appear moderate (Sabic et al., 2024).

Hospital workplaces constitute a particularly complex indoor environment from an occupational-hygiene perspective. Unlike settings dominated by a single industrial process, hospitals combine medical, laboratory, technical, and service-related activities within the same building envelope. Cleaning and disinfection procedures, clinical and laboratory work, building operation, and outdoor air infiltration occur concurrently, creating spatially and temporally heterogeneous exposure conditions for healthcare workers (Ilić et al., 2018; Božić et al., 2019). As a result, airborne chemical mixtures in hospitals may include both inorganic gases and volatile organic compounds (VOCs), originating from multiple sources that vary by department and task (Becker and Rosenberg, 2008; Fazlzadeh et al., 2015).

Although ambient air pollution has been extensively investigated, indoor air quality in hospital environments requires particular attention because exposures may be intensified by variable ventilation efficiency, episodic emission events, and continuous occupancy. Previous studies have shown that concentrations of

commonly monitored pollutants, such as carbon dioxide (CO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), formaldehyde, and VOCs, can vary substantially between hospital departments and over time. These variations reflect differences in activity patterns, chemical usage, and ventilation performance, and they may be further influenced by seasonal operating conditions (Ilić, 2015; Ilić et al., 2020; Riveron et al., 2023; Loureiro et al., 2025). Importantly, short-term concentration peaks associated with specific tasks—such as intensified cleaning or the handling of solvents—may occur even when average levels remain relatively low, underscoring the need for monitoring approaches capable of capturing temporal variability.

From an occupational-health standpoint, hospital workers represent heterogeneous exposure groups. Environmental services personnel, laboratory staff, clinical workers, and technical or maintenance employees may experience distinct exposure profiles depending on their tasks and work locations. Moreover, combined exposure to multiple airborne chemicals can result in additive, synergistic, or antagonistic effects that cannot be reliably predicted by considering individual substances in isolation (Mehmood et al., 2025). Despite this complexity, chemical exposure in healthcare settings remains insufficiently characterized relative to its importance for worker protection, particularly for support and technical staff who are often underrepresented in routine monitoring programs (Betancur et al., 2024).

FTIR spectroscopy enables simultaneous detection of multiple gaseous pollutants without preseparation, providing time-resolved exposure profiles. Although FTIR spectroscopy enables simultaneous multi-component screening, the technique is inherently based on spectral pattern recognition and may be susceptible to partial band overlap among oxygenated volatile organic compounds (e.g., alcohols and aldehydes). Therefore, careful interpretation of individual compound identification, particularly for reactive carbonyl species such as acrolein, is necessary when evaluating occupational exposure data.

In the Republic of Srpska and the wider Western Balkan region, several investigations have demonstrated the feasibility of measuring multiple chemical hazards in hospital environments and applying multivariate statistical methods to explore co-variation and potential common sources (Ilić et al., 2020). Nevertheless, systematic real-time assessments of multiple gaseous pollutants in large clinical centers remain limited. This gap is particularly evident for the summer period, when ventilation regimes, temperature-dependent emissions, and operational patterns may differ substantially from those observed during other seasons.

The present study was therefore conducted to address this gap by assessing airborne chemical hazards in selected workplaces at the Public University Clinical Center of the Republic of Srpska in Banja Luka during the summer period. Study provides a multi-component examination of exposure to gaseous chemicals in a real-time indoor hospital environment, using FTIR spectroscopy in combination with multivariate statistics. The novelty of the work lies in the integration of (i) on-site FTIR screening of multiple volatile compounds and (ii) pattern identification based on PCA to investigate potential common emission/source footprints in the context of a regional hospital in the Balkans, where such systematic real-time multi-compound exposure screening is rarely reported. Furthermore, the study highlights an applied comparison between operating theatres and other hospital areas under summer working conditions, which can influence ventilation regimes and thus exposure patterns.

MATERIALS AND METHODS

The monitoring campaign was conducted during the summer period (June 2024). Measurements were performed using a portable real-time FTIR gas analyzer operating in direct sampling mode.

A total of N = 58 indoor locations were assessed within the hospital facility. These included:

- 6 operating rooms (OR)

- 52 non-operating areas (other clinical and service rooms)

Each location represents one defined sampling point. At each location, continuous real-time FTIR measurements were performed for 5 minutes, with spectral acquisition every 30 seconds, resulting in 3000 (Acquisition / spectral range: 900–4200 cm^{-1}, spectral resolution: 8 cm^{-1}, acquisition rate: 10 spectra/s) individual spectra per location.

Concentrations of selected gaseous chemical substances in air were measured using a portable multicomponent Fourier Transform Infrared (FTIR) gas analyser Gasmet™ DX 4030 (Gasmet Technologies Oy, Finland; model DX 4030, instrument ID: 091594). The instrument belongs to the Gasmet DX4030 family of portable FTIR analysers, which are designed for simultaneous, real-time detection of multiple inorganic gases and volatile organic compounds (VOCs) in complex air matrices without prior sample preparation or preconcentration. The use of portable FTIR systems in occupational and environmental air quality studies has been widely documented in previous research on indoor air pollution, workplace exposure, and ambient air monitoring.

Ambient air was drawn directly into the analyser using the instrument's built-in sampling pump through a particulate filter mounted at the inlet to prevent dust and aerosols from entering the optical cell. No chemical derivatisation, adsorption, or thermal desorption was applied prior to analysis. This direct sampling approach enabled continuous, in situ measurements of gas-phase concentrations under real working conditions.

The analyser provided validated multigas results within less than 30 seconds per measurement cycle, which allowed high temporal resolution monitoring of concentration fluctuations associated with specific activities or ventilation changes. The sample flow rate was maintained at a constant level recommended by the manufacturer to ensure stable spectral acquisition and reproducible quantification. To ensure interpretability of inter-area comparisons, OR and non-OR locations were sampled within the same campaign window. It should be noted that because measurements were conducted sequentially across locations rather than simultaneously, temporal variability during the day may influence comparisons. This limitation is acknowledged in the Discussion.

Statistical analysis, treatment of Non-Detects and Missing Values

In the original dataset, concentrations reported as "–" represent values below the instrument detection limit (<LOD). These were not treated as zero concentrations.

For descriptive statistics, non-detect values were handled as censored data. For multivariate statistical analysis (correlation and PCA), missing values were treated using median imputation per compound, in order to avoid artificial variance inflation associated with zero substitution.

Zero replacement was avoided because it can bias variance structure and artificially inflate explained variance in PCA models.

Descriptive statistics were calculated for each compound, including mean, median, standard deviation, variance, skewness, and kurtosis. Exceedance frequency was computed relative to the occupational reference limits where available.

Pearson correlation coefficients were calculated using pairwise deletion. PCA was conducted on standardized variables (z-score) after median imputation of <LOD values. The number of retained principal components was evaluated using the Kaiser criterion (eigenvalue > 1) and inspection of the scree plot.

Pearson correlation coefficients were calculated to assess relationships between measured chemical species. A significance threshold of $p < 0.05$ was adopted, and Benjamini–Hochberg correction was applied to control for multiple comparisons.

To evaluate differences between operating rooms and other areas, Welch's t-test was conducted for each chemical species, followed by false discovery rate adjustment. Statistical analyses were performed using Python-based data science libraries.

RESULTS

For consistency throughout the Results section, the following chemical species were included in the analysis:

Carbon dioxide (CO_2); Carbon monoxide (CO); Nitrous oxide (N_2O); Methane (CH_4); Nitrogen dioxide (NO_2); Sulfur dioxide (SO_2); Acetaldehyde (C_2H_4O); Acetone (C_3H_6O); Formaldehyde (CH_2O); Benzene (C_6H_6); Toluene (C_7H_8); m-Xylene (C_8H_{10}); Isopropanol (C_3H_8O); Anhydrous ammonia (NH_3); Acrolein (C_3H_4O); Ethyl acetate ($C_4H_8O_2$); Phenol (C_6H_6O); Pyridine (C_5H_5N); Carbon disulfide (CS_2); Trichloroethylene (C_2HCl_3); Styrene (C_8H_8); Hydrogen chloride (HCl); Methanol (CH_3OH); and Ethanol (C_2H_5OH). This selection reflects substances commonly encountered in hospital indoor air as a result of cleaning and disinfection practices, laboratory activities, technical processes, and ventilation-related influences.

Descriptive statistics across the 58 locations are summarized in Table 1. Skewness and kurtosis values indicate that several compounds show highly right-skewed distributions, consistent with episodic emission events and heterogeneous indoor microenvironments.

Exceedance analysis shows that acrolein (C_3H_4O) exhibits the highest exceedance frequency relative to its reference value, while NO_2 exceedances occur in a smaller fraction of samples. Compounds such as CO_2 and alcohols show elevated levels in selected areas, consistent with occupancy and disinfection-related activities.

Table 1. Descriptive statistics of measured concentrations and number of limit exceedances across sampling locations.

Formula	Limit Values	No	Mean	Median	SD	Variance	Skewness	Kurtosis	Exceed Number	Exceed %
CO_2	5000	58	211	69.9	244	59714	0.78	-1.14	0	0
CO	20	58	0.07	0.01	0.13	0.02	2.74	8.12	0	0
N_2O	50	58	0.55	0.2	1.22	1.49	4.01	17.32	0	0
CH_4	—	58	1.18	0.72	1.17	1.36	0.69	-1.24	0	0
NO_2	0.5	58	1.2	0.11	7.26	52.74	7.59	57.78	12	20.69
SO_2	0.5	58	0.13	0.05	0.19	0.04	2.96	12.74	2	3.45
CH_3CHO	20	58	0.42	0.39	0.28	0.08	1.01	1.26	0	0
$(CH_3)2CO$	500	58	0.25	0.11	0.34	0.11	1.68	2.35	0	0
CH_2O	2	58	0.07	0.06	0.06	0	1.59	3.32	0	0
C_6H_6	1	58	0.5	0.23	1.44	2.08	7	51.51	4	6.9
C_7H_8	50	58	1.13	0.99	1.45	2.09	3.05	11.58	0	0
C_8H_{10}	50	58	0.56	0.03	1.57	2.48	4.27	19.01	0	0
C_3H_8O	400	58	0.53	0.09	0.69	0.47	1.09	-0.03	0	0
NH_3	20	58	0.11	0.03	0.41	0.17	6.11	39.67	0	0
C_3H_4O	0.02	58	1.71	1.5	1.76	3.1	4.09	24.03	57	98.28
$C_4H_8O_2$	200	58	0.31	0.03	0.99	0.98	5.15	26.85	0	0
C_6H_6O	2	58	0.06	0	0.12	0.01	2.69	7.94	0	0
C_5H_5N	5	58	0.71	0	3.08	9.49	7.04	51.76	1	1.72
CS_2	5	58	0.13	0.02	0.52	0.27	7.25	54.09	0	0
C_2HCl_3	10	58	0.03	0.01	0.04	0	2.04	3.43	0	0

C_8H_8	100	58	0.24	0.01	0.49	0.24	2.41	5.23	0	0
HCl	5	58	0.52	0.32	0.88	0.78	6.24	43.79	1	1.72
CH_3OH	200	58	0.16	0	0.38	0.15	3.52	12.83	0	0
C_2H_5OH	1000	58	1.47	0.08	2.3	5.28	1.68	2.09	0	0

[1] Rulebook on Preventive Measures for Safe and Healthy Work during Exposure to Chemical Substances (Official Gazette of the Republic of Srpska, No. 04/20).

Among all measured substances, acrolein (C_3H_4O) clearly emerged as the most critical compound. Concentrations exceeded the applied reference limit at 57 out of 58 sampling locations, corresponding to an exceedance frequency of 98.3%. This pervasive pattern indicates that acrolein represents a systematic exposure concern rather than an isolated anomaly. In contrast, nitrogen dioxide (NO_2) exceeded the corresponding limit at 12 locations (20.7%), while benzene (C_6H_6) exceeded permissible levels at four locations (6.9%). Occasional exceedances were also observed for sulfur dioxide (SO_2) and hydrogen chloride (HCl), suggesting localized or short-term emission events. For the remaining compounds, exceedances were not observed despite occasional elevated values, emphasizing that the primary occupational concern is driven by a limited subset of substances rather than uniformly elevated concentrations across all measured pollutants.

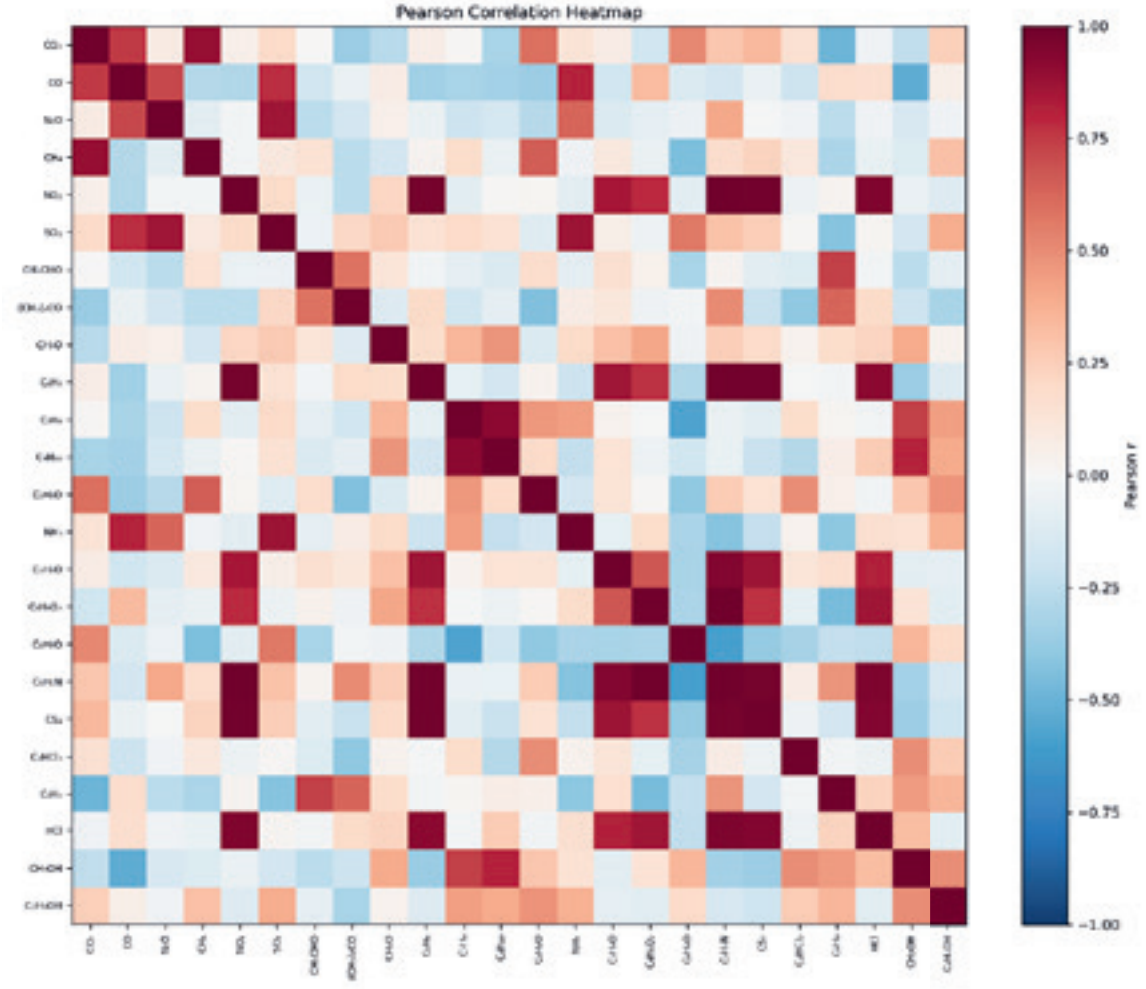

Figure 1. Correlation heatmap

Figure 1 presents the Pearson correlation heatmap illustrating linear relationships among the measured chemical species across sampling locations. Several statistically significant positive correlations were

identified, indicating that concentrations of certain compounds tended to increase or decrease concurrently. Warmer colours indicate stronger positive correlations, while cooler colours represent weak or negative relationships. The diagonal elements correspond to self-correlations (r = 1).

Notably, nitrogen dioxide (NO_2) exhibited strong positive correlations with carbon disulfide (CS_2), benzene (C_6H_6), and pyridine (C_5H_5N). These associations suggest the influence of shared emission processes or closely linked operational conditions rather than independent or random occurrence. In the context of hospital indoor environments, such co-variation may reflect combined contributions from laboratory activities, technical infrastructure, outdoor air infiltration, or ventilation system dynamics.

Additional clusters of moderate correlations were observed among aromatic and heterocyclic compounds, pointing toward source-related grouping or similar physicochemical behavior. Conversely, weak or negative correlations between certain pollutant pairs indicate divergent emission pathways, differences in chemical stability, or variable removal mechanisms such as air exchange, adsorption, or degradation. Collectively, these patterns underscore the heterogeneous and multi-pollutant nature of indoor air contamination in hospital workplaces.

Exploratory Factor Analysis (Principal Axis Factoring) was performed on standardized data after median imputation of <LOD values. The scree plot with the Kaiser threshold (Figure 2) indicates that RC1–RC6 have eigenvalues above 1 and are therefore retained according to the Kaiser criterion. RC1 explains approximately 26.2% of the variance, followed by RC2 (14.9%), RC3 (13.1%), RC4 (11.3%), RC5 (8.9%), and RC6 (4.6%).

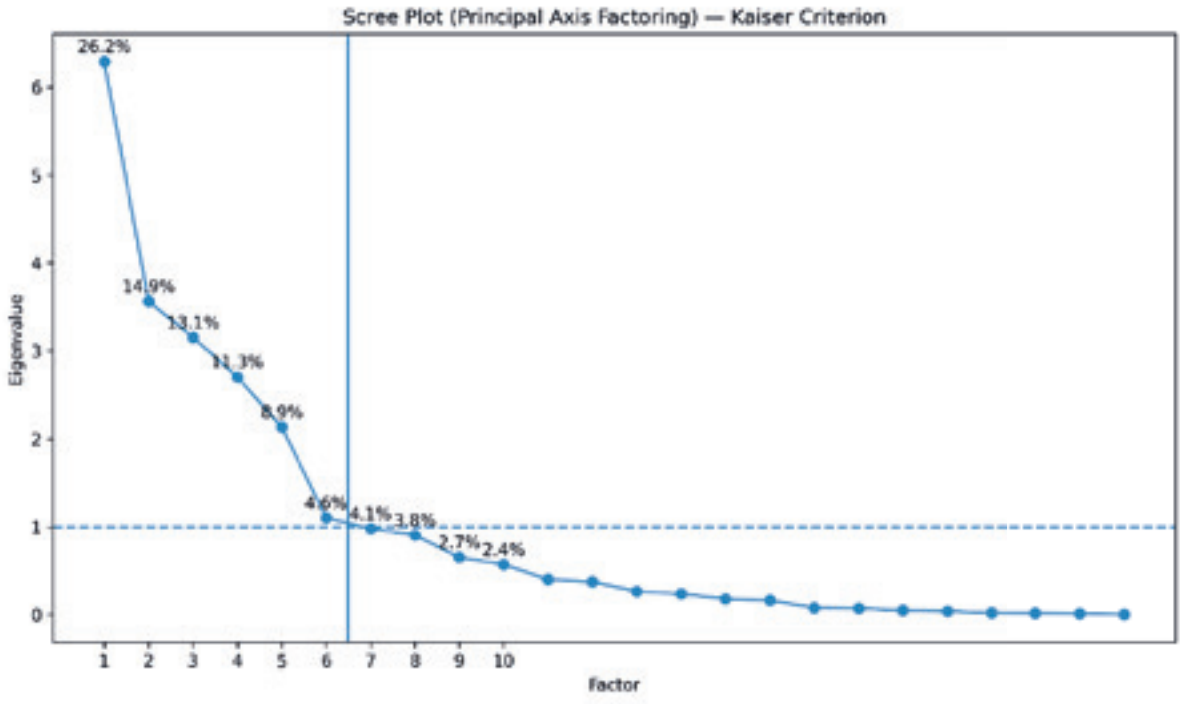

Figure 2. PCA scree plot

The cumulative explained variance shows that the first three components account for approximately 54.2% of the total variance, reaching approximately 65.4% by RC4 and approximately 79.0% by RC6. This variance distribution is consistent with real-world indoor air datasets characterized by multiple overlapping emission sources and interacting physicochemical processes rather than a single dominant factor.

The factor loading structure (Figure 3) demonstrates partial differentiation between emission patterns associated with occupancy and disinfectant use versus those linked to reactive gases and background influences. Operating rooms show greater alignment with ventilation- and disinfectant-related components, whereas other hospital areas exhibit broader dispersion, reflecting heterogeneous activities and variable ventilation regimes across the facility.

Table 2 presents the rotated factor loadings obtained from Exploratory Factor Analysis (Principal Axis Factoring) with oblique (Promax) rotation. Six rotated components (RC1–RC6) were retained based on eigenvalues greater than one according to the Kaiser criterion.

The corresponding eigenvalues were approximately 6.29 for RC1, 3.57 for RC2, 3.15 for RC3, 2.71 for RC4, 2.14 for RC5, and 1.11 for RC6, explaining 26.2%, 14.9%, 13.1%, 11.3%, 8.9%, and 4.6% of the total variance, respectively. Collectively, the six retained components accounted for approximately 79.0% of the overall variance, indicating a structured but heterogeneous multivariate system consistent with multiple partially overlapping emission sources.

Loadings with higher absolute values indicate stronger associations between individual chemical compounds and the corresponding component. Because an oblique (Promax) rotation was applied, correlations between components were permitted. Uniqueness values represent the proportion of variance in each compound not explained by the retained factors.

Formula	RC1	RC2	RC3	RC4	RC5	RC6	Uniqueness
NO_2	-0.993	0.031	0.006	0.017	-0.06	0.056	0.006
CS_2	-0.982	0.05	-0.016	0.007	-0.076	0.005	0.026
C_6H_6	-0.982	0.04	-0.024	0.044	-0.018	-0.003	0.032
C_5H_5N	-0.977	0.036	0.001	-0.007	0.095	0.063	0.032
HCl	-0.958	-0.043	0.029	-0.077	0.01	-0.047	0.071
C_8H_{10}	0.021	-0.948	-0.057	-0.149	0.02	0.001	0.074
C_7H_8	0.039	-0.944	-0.022	0.15	-0.002	-0.182	0.05
NH_3	0.024	-0.019	0.919	0.062	0.011	0.077	0.144
CO_2	-0.035	0.158	0.145	0.906	-0.161	0.013	0.105
CH_4	0.007	-0.021	-0.078	0.87	0.008	-0.087	0.23
CH_3CHO	0.006	0.096	-0.097	0.104	0.86	-0.148	0.209
CO	0.058	0.163	0.852	-0.2	-0.137	-0.2	0.146
C_3H_4O	-0.844	-0.046	-0.042	0.121	0.118	-0.222	0.207
SO2	-0.066	-0.036	0.842	0.117	0.034	0.12	0.256
CH_3OH	0.048	-0.808	-0.066	0.02	-0.189	0.305	0.211
C_8H_8	0.021	-0.025	-0.04	-0.21	0.792	0.085	0.318
$C_4H_8O_2$	-0.784	0.024	-0.012	-0.035	-0.052	-0.003	0.381
C_3H_8O	-0.028	-0.337	-0.195	0.739	0.094	0.071	0.287
$(CH_3)2CO$	0.004	0.124	0.004	-0.239	0.583	0.138	0.569
N_2O	0.042	0.139	0.567	-0.076	-0.246	-0.13	0.574
C_2H_5OH	0.094	-0.453	0.266	0.372	0.003	0.25	0.515
C_6H_6O	0.071	0.119	-0.041	-0.249	-0.26	0.418	0.675
C_2HCl_3	-0.038	-0.032	-0.041	0.356	-0.075	-0.049	0.861
CH_2O	-0.184	-0.342	0.131	-0.191	0.072	-0.221	0.742
Eigenvalue	6.293	3.565	3.156	2.704	2.135	1.103	
Variance (%)	26.2	14.9	13.1	11.3	8.9	4.6	
Total variance (Cum %)	26.2	41.1	54.2	65.5	74.4	79	

Note. Applied rotation method: Promax. Only loadings ≥ |0.001| displayed.

The first rotated component (RC1) is characterized by very strong loadings for reactive nitrogen- and sulfur-containing compounds and aromatic species, including NO_2, CS_2, benzene (C_6H_6), pyridine (C_5H_5N), hydrogen chloride (HCl), and acrolein (C_3H_4O). This pattern suggests a chemically reactive mixture potentially influenced by combined indoor–outdoor contributions, secondary reactions, and localized technical or laboratory-related activities. The dominance of oxidizing and sulfur-containing species indicates that RC1 reflects a reactive gas cluster rather than routine occupancy-driven emissions.

In contrast, the second component (RC2) is primarily associated with alcohol-based solvents and occupancy-related indicators, including isopropanol (C_3H_8O), ethanol (C_2H_5OH), acetone ($(CH_3)_2CO$), and carbon dioxide (CO_2). This component likely represents activity-driven emissions linked to cleaning, disinfection practices, and human presence, highlighting operational processes distinct from the reactive gas cluster captured by RC1.

The third and fourth components (RC3–RC4) capture additional structured variability within the dataset. Methane (CH_4) and sulfur dioxide (SO_2) exhibit relevant loadings within these factors, indicating background and combustion-related influences. These components likely reflect contributions from technical infrastructure, building energy systems, or ventilation supply air.

The fifth and sixth components (RC5–RC6) explain smaller proportions of total variance and may represent more localized or episodic emission processes rather than dominant system-wide sources. Their presence further supports the interpretation of indoor air quality in hospital environments as a multi-source and dynamically interacting system.

Table 3 presents the results of Welch's t-test comparing mean concentrations between operating rooms (OR) and other hospital areas, with Benjamini–Hochberg correction applied to control for multiple testing. Entries below the limit of detection (<LOD) were treated as missing values and excluded from group comparisons.

Statistically significant differences after correction were observed for carbon dioxide (CO_2), methane (CH_4), isopropanol (C_3H_8O), and acetone ($(CH_3)_2CO$).

CO_2, CH_4, and isopropanol concentrations were significantly higher in operating rooms, consistent with higher occupancy density and intensive use of alcohol-based disinfectants. In contrast, acetone concentrations were significantly lower in operating rooms compared with other hospital areas, suggesting differential emission patterns across functional zones.

A supplementary Mann–Whitney U test yielded comparable significance for the four dominant compounds but indicated additional marginal differences for several skewed variables. Nevertheless, Welch's test with BH correction was retained as the primary inferential framework due to unequal group sizes and variance heterogeneity.

For all remaining compounds, no statistically significant differences were detected after multiple-comparison adjustment.

Table 3. Comparison of mean concentrations between operating rooms (OR) and other hospital areas (Welch's t-test).

Formula	Mean (OR)	Mean (Other Areas)	T-Value	P-Value (BH)	Significant (P<0.05)
CO_2	639.233	170.998	13.895	1.37e-16	Yes
CH_4	2.795	1.057	10.713	6.69e-14	Yes
C_3H_8O	1.940	0.604	8.546	1.31e-05	Yes
CO	—	—	—	—	No*
C_6H_6O	—	—	—	—	No*
C_8H_8	—	—	—	—	No*

C_7H_8	1.670	1.318	1.342	2.79e-01	No
C_2HCL_3	0.088	0.044	2.107	1.54e-01	No
C_2H_5OH	4.403	2.358	1.897	1.90e-01	No
C_8H_{10}	0.068	0.967	−2.574	5.34e-02	No
$C_4H_8O_2$	0.053	0.690	−2.308	8.84e-02	No
HCL	0.273	0.573	−2.143	9.43e-02	No
CS_2	—	—	—	—	No*
$(CH_3)_2CO$	0.150	0.440	−3.876	2.18e-03	Yes
C_5H_5N	—	—	—	—	No*
C_2H_4O	—	—	—	—	No*
CH_2O	0.042	0.079	−1.579	2.63e-01	No
C_6H_6	0.250	0.631	−1.501	2.52e-01	No
N_2O	0.623	0.556	0.350	8.74e-01	No
NO_2	0.297	2.052	−1.049	4.18e-01	No
SO_2	0.210	0.206	0.058	9.91e-01	No
NH_3	0.162	0.151	0.117	9.91e-01	No
C_3H_4O	1.623	1.755	−0.475	8.19e-01	No
CH_3OH	0.330	0.332	−0.011	9.91e-01	No

"-" indicates insufficient valid measurements above the limit of detection (<LOD) within one or both groups to perform a reliable Welch's t-test.

For CO_2, CH_4, and isopropanol (C_3H_8O), mean concentrations were significantly higher in operating rooms compared with other hospital areas, consistent with higher occupancy density, controlled ventilation regimes, and the frequent use of alcohol-based disinfectants in these areas. Acetone ($(CH_3)_2CO$) exhibited significantly lower concentrations in operating rooms relative to other hospital areas, indicating potential differences in solvent-related emission patterns across functional hospital zones. For all remaining compounds, no statistically significant differences were detected after Benjamini–Hochberg correction. This suggests broadly comparable concentration levels across hospital areas for these substances and supports the interpretation of a heterogeneous but partially overlapping emission structure within the hospital environment.

DISCUSSION

The results of this study indicate that chemical exposure in hospital workplaces is governed by pronounced spatial heterogeneity and the coexistence of multiple gaseous pollutants, rather than by a single dominant emission source. Such heterogeneity is consistent with previous investigations of hospital indoor air quality, which have emphasized the combined influence of ventilation design, occupancy patterns, building characteristics, and cleaning and disinfection practices on airborne chemical composition (Saraga et al., 2011; de Carvalho et al., 2020). The present findings reinforce the view that hospital indoor air represents a dynamic system in which pollutant concentrations respond continuously to routine activities as well as to episodic events, rather than remaining at steady-state levels.

The most critical observation emerging from this study is the pervasive exceedance of acrolein (C_3H_4O), which exceeded the applied reference value at nearly all sampling locations. Acrolein is a highly reactive unsaturated aldehyde with well-established respiratory toxicity, capable of inducing airway inflammation, oxidative stress, and epithelial injury even at relatively low concentrations (Bein and Leikauf, 2011; Leikauf et al., 2011; Ghilarducci and Tjeerdema, 1995). Importantly, given that the present study employed FTIR-based real-time screening, the potential influence of spectral overlap with other oxygen-

ated volatile organic compounds (e.g., alcohols and carbonyl compounds) should be considered when interpreting the magnitude of measured concentrations. Although ethanol and isopropanol concentrations were generally below occupational limit values, their frequent use in hospital environments may still affect FTIR spectral fitting due to partial overlap in infrared absorption regions. While the multicomponent FTIR algorithm accounts for these compounds explicitly, the possibility of residual spectral interference, particularly for acrolein, cannot be fully excluded. Therefore, the reported acrolein exceedances should be interpreted with caution and considered indicative of a potential issue rather than definitive quantitative confirmation. While the widespread nature of the exceedances suggests that acrolein-related exposure may not be confined to isolated hotspots, confirmatory analytical measurements would strengthen the attribution of this signal exclusively to acrolein. Broader operational conditions, such as the use of specific chemical products, secondary formation reactions involving disinfectants, or ventilation regimes favoring accumulation during certain periods, likely contribute to the observed pattern. Similar concerns regarding aldehyde exposure in healthcare settings have been raised in occupational hygiene studies, particularly in environments characterized by intensive cleaning and disinfection activities (Logue et al., 2011; Nielsen et al., 2013; Ilić et al., 2020).

Nitrogen dioxide (NO_2) exceeded permissible levels at a subset of locations, indicating that reactive inorganic gases contribute to the overall exposure profile, although less consistently than acrolein. Although hospitals are not typically considered combustion-intensive environments, indoor NO_2 has been shown to originate from outdoor air infiltration, emergency power systems, medical or technical equipment, and inefficiencies in ventilation performance (Weschler, 2006; Brook et al., 2010; Morawska et al., 2013). The spatial variability observed in the present study suggests that local room characteristics and air-handling strategies play a decisive role in determining NO_2 concentrations, in line with previous observations in healthcare facilities (Daisey et al., 2003; Rouadi et al., 2010; Radović et al., 2022).

The detection of benzene (C_6H_6) exceedances at several locations is of particular relevance from an occupational-risk perspective, given its classification as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC, 2012). While benzene is most commonly associated with fuel combustion and industrial activities, its presence in hospital indoor air has been reported in relation to outdoor traffic infiltration, building materials, and certain laboratory or technical processes. Even though exceedances were observed at a limited number of locations, their occurrence underscores the importance of considering low-frequency but high-risk exposures within comprehensive workplace risk management frameworks.

Correlation analysis provided additional insight into potential relationships among measured pollutants. The strong positive associations observed between NO_2, carbon disulfide (CS_2), benzene, and pyridine indicate that these compounds tend to co-occur under similar environmental conditions. Although correlation does not imply causation, such co-variation patterns are commonly interpreted as evidence of shared emission processes or common controlling factors, such as ventilation performance or combined indoor–outdoor contributions. Comparable associations have been reported in previous indoor air studies, where reactive nitrogen oxides, aromatic hydrocarbons, and sulfur-containing compounds were linked through ventilation-driven mixing or overlapping source influences (de Carvalho et al., 2020).

The principal component analysis further supports the interpretation that hospital air quality is shaped by multiple partially independent processes. The retention of several components explaining a substantial proportion of the total variance indicates that no single factor dominates the chemical composition of indoor air. Instead, different components likely reflect background ventilation-related influences, activity-driven emissions associated with cleaning and solvent use, and more localized or episodic contributions from technical or laboratory operations. Importantly, the identification of a component strongly influenced

by acrolein suggests that this compound follows a distinct variation pattern embedded within a broader mixture of reactive gases, rather than behaving as an isolated pollutant.

Differences observed between operating rooms and other hospital areas provide additional context for interpreting the exposure patterns. Higher concentrations of carbon dioxide, methane, and isopropanol in operating rooms are consistent with elevated occupancy, controlled ventilation regimes, and intensive use of alcohol-based products during clinical procedures (Seppänen and Fisk, 2004). The importance of optimized ventilation performance in critical care environments, including operating rooms and intensive care units, has been emphasized in previous studies addressing airflow control, contaminant dilution, and pressure differentials in healthcare settings (Saran et al., 2020). This finding aligns with previous studies demonstrating that operating rooms generally maintain stricter air quality control than general wards or technical areas (Memarzadeh and Manning, 2002).

Overall, the present findings highlight that chemical exposure in hospital workplaces is driven by a combination of background conditions and activity-specific processes, resulting in complex and temporally variable exposure patterns. From an occupational-health perspective, this complexity underscores the limitations of assessment strategies based solely on average concentrations or a narrow set of indicators, and it emphasizes the value of real-time, multicomponent monitoring approaches for identifying priority pollutants and guiding targeted risk management measures.

CONCLUSION

This study provides original real-time evidence on airborne chemical exposure in hospital workplaces during the summer period, demonstrating that indoor air quality is characterized by pronounced spatial heterogeneity and activity-driven concentration fluctuations rather than uniform background conditions. The results confirm that chemical exposure in healthcare facilities is governed by multiple concurrent factors, including ventilation performance, chemical product usage, occupancy density, and operational practices, which together shape complex and temporally variable exposure patterns.

A key outcome of this investigation is the identification of acrolein as a critical pollutant of occupational-health relevance. The near-ubiquitous exceedance of reference values for acrolein suggests that aldehyde-related exposure may represent a relevant occupational-health concern under the investigated summer operating conditions. However, given the screening-based analytical approach, further confirmatory measurements are warranted before definitive regulatory conclusions are drawn.

Differences observed between operating rooms and other hospital areas further emphasize that chemical exposure cannot be adequately addressed through generalized indoor air quality assumptions. Area-specific exposure profiles, shaped by distinct activities and ventilation characteristics, require differentiated assessment and control strategies. The results therefore support a shift from uniform monitoring approaches toward more context-sensitive occupational hygiene practices within healthcare facilities.

Although the present study is based on real-time screening measurements, it provides a robust framework for identifying priority substances and exposure scenarios that warrant further investigation. The observed frequency and magnitude of exceedances for selected pollutants, particularly acrolein, suggest that existing ventilation and chemical management practices may require reassessment under certain seasonal operating conditions. These findings highlight the importance of integrating continuous or high-temporal-resolution air quality monitoring into occupational health programs to support evidence-based decision-making and protect healthcare workers' health.

Conflict of Interest
The authors declare no conflict of interest.

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Recived: November 31, 2025

Accepted: January 16, 2026

DOI: 10.7251/QOL2601058L **UDC:** 616.853-052:616.89-008

Review Paper

Prevention of Suicidal Behavior in Patients with Depressive Disorder – The Role of the Nurse

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Abstract: Depressive disorder represents one of the most common and complex mental illnesses of modern society, with suicidal behavior being its most severe and dangerous consequence. Suicide prevention among individuals suffering from depressive disorder requires a multidisciplinary approach in which the nurse plays a key role. Since nurses most often establish the first and most intensive contact with patients, they have a crucial role in the early recognition of suicidal risk indicators, providing support, and implementing appropriate interventions. The aim of this paper is to highlight the importance of the nurse's role in the prevention of suicidal behavior among patients with depressive disorders, through the analysis of responsibilities, competencies, and duties arising from everyday clinical practice. Numerous studies confirm that continuous education, well-developed communication skills, empathy, and clearly defined work procedures contribute to improving patient safety and the overall quality of healthcare. Through a professional and humanistic approach, the nurse becomes a key link in the chain of suicide prevention, providing not only care but also restoring hope and dignity to individuals in a state of deep psychological crisis.

Keywords: depressive disorder, suicidal behavior, nurse, suicide prevention, healthcare, empathy.

INTRODUCTION

Suicide and suicidal behavior represent a serious global public health problem with increasing social, economic, and psychological consequences. The World Health Organization estimates that around 800,000 people worldwide lose their lives to suicide each year, while the number of suicide attempts is significantly higher—ranging from 10 to 40 times the number of completed suicides (WHO, 2019). These data point to the urgent need for the development of effective preventive programs and multidisciplinary approaches, within which healthcare professionals, particularly nurses, play an indisputable and vital role.

Depressive disorder is one of the most significant risk factors for the development of suicidal thoughts and behaviors. In most cases, suicidal tendencies arise as a result of a complex interaction of biological, psychological, and social factors (Nock, Ramirez & Rankin, 2019). Due to this complexity, the process of recognizing and treating suicidal risk requires a holistic approach that includes not only pharmacotherapy and psychotherapy but also continuous nursing care and emotional support for the patient.

Nursing care for patients with depressive disorders involves constant observation, risk assessment, and the implementation of appropriate nursing interventions aimed at alleviating symptoms and preventing the occurrence of suicidal thoughts and behaviors. Through professional ethics, empathy, and expertise, the nurse acts not only as a caregiver but also as an educator, counselor, and intermediary between the patient, the family, and the medical team. It is particularly important to emphasize that every intervention should be based on scientific evidence while being tailored to the individual needs and emotional state of the patient.

The aim of this paper is to highlight the importance of the nurse's role in preventing suicidal behavior among patients with depressive disorders through an analysis of risk factors, specific interventions, and approaches that contribute to reducing suicidal tendencies. In addition, the paper aims to emphasize the need for continuous education and professional development of nurses in the field of mental health, as well as the importance of teamwork and an empathetic approach in everyday clinical practice.

Depressive Disorder as a Risk Factor for Suicidal Behavior

According to available research, approximately 70% of individuals who commit suicide suffer from depression (Aros, 2008). The prevalence of depressive disorder in the general population ranges between 3.6% and 6.8%, with a higher occurrence among women than men (Marčinko, 2011). It is estimated that 10–15% of people with depressive disorder die by suicide, making depression one of the most significant individual risk factors for suicidal behavior. When assessing suicide risk, it is essential to systematically consider symptoms of anxiety, as depression frequently co-occurs with anxiety, further increasing the risk. Diagnostic criteria for depressive disorder explicitly include recurrent thoughts of death, suicidal ideation, and/or suicide attempts; thus, suicide attempts or completed suicides are regarded as the most severe possible outcomes of depression. Suicide often occurs in the early stages of the illness, with psychotic symptoms, panic attacks, high anxiety levels, and the use of alcohol or other psychoactive substances contributing to increased risk (Brečić, 2017).

Given that depression can have an episodic course, a thorough evaluation of both personal and family medical history is crucial for a comprehensive understanding of the current risk. The likelihood of suicide is considerably higher among individuals with depression accompanied by psychotic features, a history of previous suicide attempts, a positive family history of suicide, or comorbid substance use (3,6). Conversely, protective factors such as a stable family network, social support, and community engagement have a significant mitigating effect, reducing the likelihood of suicidal behavior. Moreover, continuous therapeutic alliance, accessibility of professional help, and early intervention can act as protective mechanisms by decreasing symptom burden and strengthening coping strategies, thereby contributing to the prevention of adverse outcomes in individuals with depressive disorder.

Nursing Care of Patients With Depressive Disorder

The nursing care process represents a systematic and structured framework that enables the identification, analysis, and resolution of the patient's needs and problems within the field of nursing care. This process consists of four fundamental phases: assessment of needs, planning, implementation, and evaluation (Fučkar, 1995).

In the context of patients with depressive disorder and suicidal behavior, each of these phases holds specific importance. Particular emphasis is placed on the phases of needs assessment and evaluation, as they allow for the timely recognition of suicidal thoughts, emotional changes, and the need for additional protective measures. In this way, the nursing care process not only contributes to improving the quality of healthcare but also plays a crucial role in the prevention of suicidal behavior among at-risk patients.

The Role of the Nurse in the Prevention of Suicidal Behavior

The process of nursing care is based on professional knowledge and a rational approach to recognizing and solving the patient's problems. It includes assessing the patient's condition, identifying existing difficulties, developing a care plan, and providing continuous nursing attention throughout the treatment and rehabilitation process.

Nurses and technicians play a key role in assessing and managing patients with suicidal behavior. The assessment process begins at the very first contact with the patient, whether they have sought help due to symptoms, or have been hospitalized following a suicide attempt or self-harming behavior. Professional knowledge of the phenomenology of suicidality enables nursing staff to provide appropriate support, recognize risk factors, and intervene promptly. Patients at increased risk require continuous monitoring and observation, and every verbal or non-verbal threat of suicide must be taken seriously,

since most attempts do not stem from a true desire to die but represent a cry for help and a need for understanding (Muk, 2014).

In providing care, the nurse should establish a relationship of trust and empathy with the patient, encouraging them to express their feelings and thoughts. Through active listening and non-intrusive conversation, it becomes possible to gain insight into the patient's life attitudes and assess the level of suicidal risk. If there is suspicion, the patient must be asked directly about possible suicidal intentions. Special attention should be given to observing nonverbal cues, depressive behavior, and mood changes.

During nursing care, it is essential to ensure a safe environment—removing potentially dangerous objects, regularly checking the patient's belongings, and preventing access to medications. Nursing staff should be particularly cautious during periods of apparent improvement, as sudden calmness or symptom withdrawal may precede a suicide attempt (Marčinko, 2022).

The primary goal of nursing care for suicidal patients is to strengthen their will to abandon suicidal thoughts and find new ways of coping with difficulties. It is important to motivate them to participate in sociotherapeutic activities and develop positive behavioral patterns. All interventions and observations must be carefully documented in nursing records, including circumstances, consequences, and all forms of self-harm (Muk, 2014).

The nurse's role extends beyond direct care to include patient education about risk factors and methods of preventing suicidal behavior. A professional approach excludes criticism, judgment, or superficial reassurance, while emphasizing adherence to ethical and communication standards. Continuous education, professional development, and emotional maturity of nurses and technicians form the foundation of high-quality and safe care for patients at risk of suicide (Muk, 2014).

The nurse is often the first contact for patients with pronounced suicidal thoughts or behavior, whether working in a family medicine practice, emergency medical service, or hospital emergency department. In such cases, the nurse must approach the patient seriously and empathetically, carefully listen to their concerns, try to understand the cause of the problem, and refer the patient or their companions to appropriate professional help. A person showing suicidal tendencies should never be left alone; it is necessary to assess and remove access to potentially dangerous objects, medications, or substances to ensure safety for the patient and others.

Patient assessment is based on a rapid and comprehensive evaluation of mental and emotional status, including observation of appearance, behavior, mood, and general emotional expression. Patients with mental health difficulties most often arrive accompanied by healthcare or police officers, social workers, or family members, and rarely alone. In such cases, the nurse must urgently assess the level of risk—particularly in patients with previously diagnosed mental illnesses, acute crises, or symptoms suggesting self-harm or potential harm to others (Slavetić & Važanić, 2012).

The Australasian Triage Scale is used in assessing patients' mental health, determining the urgency of medical intervention. If the nurse assesses that the patient poses an immediate danger to themselves or others, it is necessary to implement safety measures and establish constant visual supervision. Such patients should not wait in the waiting area but receive immediate medical evaluation and intervention (Slavetić & Važanić, 2012).

DISCUSSION

Suicide prevention within nursing care—especially among patients with depressive disorder—requires a comprehensive and coordinated approach that includes professional expertise, experience, and emotional competence of nurses. Research shows that nurses are crucial in the early recognition of suicidal

thoughts and risks, building trust with patients, and implementing preventive interventions across different levels of healthcare (11, 12). Their role in acute and intensive care is particularly significant, as they are often the first to encounter suicidal patients and thus bear responsibility for initial risk assessment and environmental safety.

Studies indicate that experience significantly enhances nurses' confidence and readiness to engage in discussions about suicidal thoughts. A lack of experience, formal education, and clear guidelines often leads to uncertainty and fear of misjudgment, particularly among younger staff. In situations where procedures are not clearly defined, nurses often rely on intuition and personal experience—highlighting the need for standardization and continuous education in this field (13, 14). In accordance with World Health Organization recommendations (WHO, 2014), it is essential to strengthen the competencies of healthcare professionals in suicide prevention through formal educational programs that enhance knowledge, attitudes, and confidence in working with suicidal patients (Giacchero Vedana et al., 2017).

One of the most prominent challenges in clinical practice is the lack of time for individual conversations with patients. Numerous studies have confirmed that it is precisely through conversation that the nurse can best identify suicidal thoughts and build the trust essential for uncovering the patient's true psychological state (17, 18). Lack of time and staffing, combined with high emotional demands, create barriers to effective suicide prevention. Therefore, it is vital that healthcare institutions provide organizational support—by allocating uninterrupted time for communication and implementing clear protocols for risk assessment and monitoring.

Beyond experience and organizational limitations, research emphasizes the importance of education and emotional literacy among nurses. Those who have undergone training in suicidality and mental health display higher professional confidence, greater readiness to ask direct questions about suicidal intent, and increased empathy when communicating with patients. Even short educational formats—such as brief workshops—have proven effective in improving competence and shifting attitudes toward suicidal patients (Solin et al., 2021).

Another critical factor is the stigma surrounding mental illness, which remains a barrier to effective suicide prevention. Negative attitudes and fear toward mentally ill individuals, especially among less experienced nurses, can lead to avoidance of communication, inadequate risk assessment, and a lack of empathy in care provision (Hastings et al., 2017). Education helps reduce stigma, enhances professional motivation, and strengthens nurses' commitment to active participation in suicide prevention.

Organizationally, unclear responsibilities and poor collaboration between somatic, primary, and psychiatric healthcare levels have been observed. The absence of clear protocols increases nurses' personal sense of responsibility and stress—especially in cases where suicide occurs under their supervision (Vandewalle et al., 2019). Improving intersectoral collaboration and involving family members in care can significantly enhance suicide prevention, as relatives often possess valuable information about the patient's condition and behavior.

According to humanistic nursing models, success in suicide prevention depends not only on technical competence but also on the nurse's ability to establish a "human-to-human" relationship based on trust, respect, and active listening (Staskova & Tothova, 2015). By integrating professional knowledge with a therapeutic approach, the nurse can alleviate suffering, restore hope, and strengthen the patient's desire to live.

Finally, findings point to the need for systemic support in the form of clear guidelines, continuous education, emotional supervision, and adequate work organization. Suicide prevention requires nurses to possess both formal and practical competencies as well as emotional stability. Only through the combina-

tion of expertise and empathy can the ultimate goal be achieved—timely recognition and prevention of suicidal behavior among patients with depressive disorder.

CONCLUSION

Depressive disorder represents one of the most severe and widespread mental illnesses of modern society, with suicidal behavior as its most dangerous and tragic manifestation. Although depression and suicide are still often discussed in society with insufficient understanding, their significance extends far beyond medical boundaries — they constitute phenomena with deep psychological, social, and ethical dimensions. Within this complex framework, the nurse occupies an exceptionally important position, being the healthcare professional who spends the most time with the patient and bridges the clinical and human aspects of care.

Effective suicide prevention requires nurses to possess highly developed skills of observation, communication, and assessment, as well as an understanding of the psychopathological processes and emotional reactions of those affected. The essence of nursing care lies not only in performing therapeutic interventions but also in the ability to recognize suffering, offer support, and build a relationship of trust that restores the patient's sense of value and belonging. Through empathy, professionalism, and open communication, the nurse can become a crucial factor in breaking the cycle of hopelessness that leads to suicidal thoughts and actions.

Although science and medicine today provide advanced methods for treating depression and preventing suicide, they alone are not sufficient. A joint, multidisciplinary effort of all actors is needed to create a system that not only heals but also understands and supports. At the same time, it must be acknowledged that despite all efforts, it is not always possible to save every life. Nevertheless, what can and must always be done is to offer understanding, time, and presence — for that is the true essence of the nursing vocation: to stand by a person in their deepest crisis and help them rediscover hope where it once seemed lost.

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Recived: October 20, 2025
Accepted: November 5, 2025

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It is particularly important that the introductory part be as brief as possible and clear in description of the aims of investigation. Previous relevant work regarding the topic of the manuscript should be included with references.

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Conclusion

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Acknowledgements

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ISSN 1986-6020