LEGIONELLA SPP. IN AIR-CONDITIONING SYSTEMS OF PUBLIC FACILITIES IN THE SARAJEVO CANTON: THE ROLE OF MANAGEMENT AND EMPLOYEE ABSENTEEISM

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ABSTRACT

Introduction: *Legionella spp.* is opportunistic pathogenic bacteria that cause two forms of the disease: more severe, more frequently diagnosed - Legionnaires' disease, and milder, less frequently diagnosed Pontiac fever.

Research objectives: The primary objective of the study was to examine the presence of *Legionella spp.* in the air conditioning systems of the studied facilities.

Methods: The study was conducted in the Sarajevo Canton, Federation of Bosnia and Herzegovina. The research included air conditioning systems in public facilities. Sampling was carried out over a two-year period. Water samples and samples collected using the wet swab method were obtained. The samples were laboratory analyzed for the presence of *Legionella spp.* in accordance with a standard method. During the period of sample analysis, the laboratory was undergoing accreditation in accordance with the relevant standard. A survey was also conducted in the included facilities.

Results: *Legionella spp.* was detected in air conditioning devices of 8 (21%) facilities. No relation was established between knowledge, external education and management with bacterial colonization. Internal training of employees is carried out in three (37.5%) facilities compared to eight facilities in which bacteria were detected ($p<0.05$). Also, bacteria detected in 4 (40%) facilities where employee absenteeism was associated with respiratory diseases ($p<0.05$).

Conclusion: The results emphasize the need for a systemic approach to risk management and the improvement of practices that contribute to safer stay of users and employees in the air-conditioned spaces of public facilities in the Sarajevo Canton.

Keywords: *Legionella*, Bacterial Colonization, Education, Risk Factors, Facility Users.

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INTRODUCTION

One of the most important factors influencing human health are the conditions in which a person lives and works, which are often difficult to change but it is important to try to improve them, which again depends on the socio-economic situation of a society and political interest (1). In recent decades, there have been sudden climate changes as well as harmful effects on human health (2). However, regardless of the external climate, people have always strived to ensure favorable conditions and achieve comfort indoors. The most favorable conditions for humans are at a temperature around 20 °C and a relative humidity around 50% (3). High temperatures in the workplace can significantly reduce work productivity, especially when it comes to work that requires focus and precision. Studies show that productivity especially decreases at temperatures above 35 °C, which is additionally affected by the duration of exposure and air humidity (4-6). Therefore, although staying in an air-conditioned space has many other positive effects on human health in addition to the aforementioned, it can also lead to serious illness caused by contamination of the air conditioning devices with bacteria from the genus *Legionella* (*L.* spp.). Based on the analysis of professional literature, air conditioning devices are a frequent source of *L.* spp (7-9). There is evidence that legionellosis is associated with occupational exposure in various work settings. The risk has been recorded in a wide range of occupations, including industrial plants, healthcare facilities, offices, construction sites, water systems and transport. The main route of infection is inhalation of aerosols contaminated with *L.* spp., where cooling towers and air conditioning devices are particularly important, as they represent key sources of aerosolization of contaminated water and potential spread of the disease (10). Visitors to public and commercial facilities, including hospitals, hotels, recreational and shopping centers, may be exposed to *L.* spp., especially when systems are not properly maintained and controlled. Shopping centers have been identified as potential sites of visitor exposure due to the complexity and intensively used water systems (11, 12). Prolonged exposure to contaminated aerosols with a high concentration of bacteria increases the total dose of inhaled bacteria and thus there is a greater risk and possibility of disease development, especially in a closed or space where the issue of ventilation is poorly resolved (13). Risk management of *L.* spp. in water systems significantly depends on the knowledge, attitudes and perception of the management and persons responsible for the facility maintenance. Managers of facilities often do not have clearly defined strategies for controlling *L.* spp., in addition, lack of awareness, formal plans and education of employees represent an obstacle in the effective prevention of contamination of water systems (14). In facilities with a complex installation and an increased risk of aerosol formation, the training of technical personnel responsible for the maintenance of these systems is of crucial importance for the efficient application of preventive measures and the reduction of the risk of *L.* spp. colonization (15). Asymptomatic infections caused by *L.* spp. are common in humans (8). Global seroepidemiological studies show that about 13-14% of people had antibodies to *L.* spp., which indicates significant earlier exposure to the bacterium, including subclinical and milder forms of the disease (16). The severe form of Legionnaires' disease (LD), even in immunocompetent individuals, represents a significant public health challenge, as it requires intensive medical care,

extended hospital treatment and resources to prevent the spread of the bacteria. In addition, early recognition of the disease is difficult due to non-specific symptoms, which further emphasizes the importance of adequate diagnostics and community surveillance (17). Although Pontiac fever is a milder form of the disease (18) in the event of an epidemic, a high incidence rate is predominantly recorded in the affected group (19). The prevalence of LD in a country is greatly influenced by a well-developed and effective surveillance program, the health system, the climate, and the economic situation of the country (20). In the study area, in the context of worker exposure, the Law on Occupational Safety of the Federation of Bosnia and Herzegovina prescribes general rules for health and safety protection, including risk assessment and ensuring a safe working environment. The Law does not explicitly mention *L.* spp. or air conditioning devices, biological risks such as *L.* spp. are covered only through general provisions on risk assessment (21). The Law on the Protection of the Population from Infectious Diseases clearly states that LD is an infectious disease, and that reporting is mandatory (22). Preventive measures against legionellosis are implemented based on the guidelines and instructions of the Institute of Public Health of the Federation of Bosnia and Herzegovina (23).

The main goals of the research was to analyze the collected samples from the air conditioning devices of public facilities for *L.* spp. colonization and establish the prevalence. Other goals of the research was: To examine the relationship between the presence of *L.* spp. in air conditioning devices with the management's perception and implementation of preventive activities the appointment of the responsible person for monitoring the operation of air conditioning devices and employee absenteeism related to respiratory diseases.

MATERIAL AND METHODS

The research was conducted in the area of Sarajevo Canton, Federation of Bosnia and Herzegovina, Bosnia and Herzegovina (2023-2024). The research included public facilities where the presence of *L.* spp. in air conditioning devices was tested. The criteria for inclusion in the research were: the size of the facility, the number of employees and the frequency of visitors. Smaller and rarely visited facilities are not included in the research. In total, 38 facilities were included in the study and classified into four categories. The most represented were service facilities (N = 21; 55.2%), followed by office buildings (N = 9; 23.7%) and tourism and hospitality facilities (N = 6; 15.8%), while healthcare institutions were the least represented (N = 2; 5.2%). In total, 80 samples were collected, of which 24 (30.0%) were water samples and 56 (70.0%) samples were collected using the wet swab method. The representative sample was determined based on a 10% probability of detecting the presence of *L.* spp. in air-conditioning systems of public facilities in the Canton of Sarajevo. The sample size was calculated based on an accepted margin of error of 5% and a desired confidence level of at least 95%. Method 19458:2008 was used for water sampling (24), while method 18593:2019 was used for collecting samples with a wet swab (25). The sampling location was previously defined (water tank, filter, diffuser, turbine, condensation vessel, cooling tower) and based on scientific and expert evidence on the risk components of air conditioning devices associated with *L.* spp. The samples were transported in a portable refrigerator (up to 8 ºC), and were delivered to the laboratory for microbiological analysis as

soon as possible. The laboratory was in the process of accreditation according to the requirements of standard 17025:2018 (26). Detection and counting of *L.* spp. of all analyzed samples was carried out by cultivation, while water samples, due to water with a low number of bacteria, were also membrane filtered. Sowing was carried out on media with buffer agar of yeast extract and activated carbon (BCYE) (Liofilchem, Italy). Incubation on the substrate at a temperature of 36 °C in a humid environment with 2.5% CO_2 lasted for ten days. Examination with a dissecting microscope was performed on the third and fifth day (11731-2:2018) (27). In addition, in each of the facilities was conducted a previously structured interview using a paper standardized survey questionnaire. The survey questions were answered by persons in charge of maintaining air conditioning systems, managers or deputies of the investigated facilities. The questionnaire used is exclusively the author's work, and was created based on a review of numerous professional and scientific literature, recommendations from authorized air conditioning services and on the basis of previous competence and expected evidence in practice. The questionnaire consisted of five questions. The questions were of closed type. Four questions were answered YES/NO, while the fifth question was answered Yes/No/Moderately.

Written consent for the implementation of the study was obtained from the management of all included facilities, along with a signed statement ensuring the anonymity of the collected data and the results of the analyzed samples. Ethical approval was not required, as the study did not involve the analysis of human or animal material, nor the processing of participants' personal data.

Statistical methods

The research results are presented in forms of tables and/or charts by absolute number and percentage. The chi-square test was used to test the differences. 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

A total of 38 facilities were investigated, of which *L.* spp. was detected in air conditioning devices in 8 (21.1%) (Figure 1).

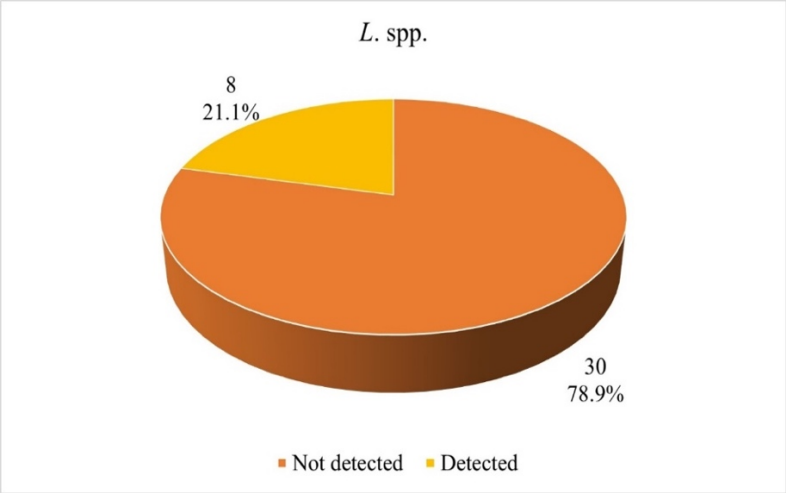

Figure 1. *Detection of L. spp. in the facilities (N=38)*
Legend: *L.* spp. - bacteria from the genus *Legionella;*

Results show that *L.* spp. was isolated in 17 samples (21.2%) out of a total of 80 collected and analyzed samples (Figure 2).

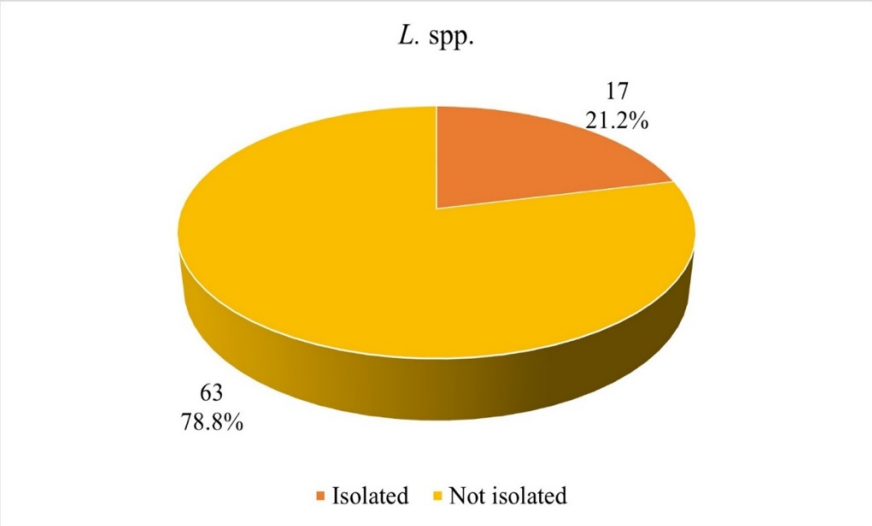

Figure 2. *Presentation of the findings of the analyzed samples for L. spp. (N=80)*
Legend: *L.* spp. - bacteria from the genus *Legionella;*

Collected survey responses on management's perception regarding *L.* spp. and implementation of activities - potential risks of bacterial colonization in air conditioning devices are presented. Statistical analysis was performed on the basis of the presence of *L.* spp. in the air conditioning devices of the investigated facilities and the collected survey responses to the four questions. There was a lower representation of facilities where *L.* spp. was detected in air-conditioning devices where internal training of employees is carried out compared to the other group of facilities, the result obtained using the chi-square test showed a statistically significant difference ($p<0.05$). Statistical analysis using the chi-square test, survey responses to the remaining three questions, and comparison of the two groups of objects did not reveal statistically significant differences. Knowledge regarding the risks associated with bacteria and colonization in air conditioning devices is at a satisfactory level, however, no statistically significant difference was recorded between the two groups of facilities. Furthermore, a small representation of facilities 5 (13.2%) in which external educations are organized was observed, where also the result of the statistical analysis did not show a statistically significant difference between the two groups of facilities. Although 28 (73.7%) facilities employed a person for supervision and monitoring, in this group of facilities *L.* spp. was detected in the air conditioning devices of 7 (87.5%) facilities compared to the second group of facilities where the bacteria was detected in the air conditioning device of one (12.5%) facility, where no statistically significant difference was recorded (Table 1).

Table 1. *The presence of L. spp. in air conditioning devices and the connection with the collected survey answers (N = 38)*

			L. spp.		Total
			Not detected	Detected	
Opinion on whether the presence of *L.* spp. in the air conditioning device, endanger people's health $\chi2 = 0.042$; p = 0.629	No	N	3	1	4
		%	10.0	12.5	10.5
	Yes	N	27	7	34
		%	90.0	87.5	89.5
Attending seminars or educational programs related to the issue of *L.* spp. $\chi2 = 0.004$; p = 0.721	No	N	26	7	33
		%	86.7	87.5	86.8
	Yes	N	4	1	5
		%	13.3	12.5	13.2
Organization of internal training for employees $\chi2 = 5.234$; p = 0.002	No	N	12	5	17
		%	40.0	62.5	44.7
	Yes	N	18	3	21
		%	60.0	37.5	55.3
Employee responsible for supervising and monitoring the operation of the air conditioning device $\chi2 = 0.997$; p = 0.306	No	N	9	1	10
		%	30.0	12.5	26.3
	Yes	N	21	7	28
		%	70.0	87.5	73.7
Total		N	30	8	38
		%	78.9	21.1	100.0

Legend: *L.* spp. - bacteria from the genus *Legionella;*

One of the survey questions related to employee absenteeism in facilities related to respiratory diseases, and the following table shows the collected survey responses from the surveyed facilities. Statistical analysis was conducted based on the presence of *L.* spp. in the air conditioning devices of the facilities and the collected survey responses. The result of the statistical analysis using the chi-square test showed that there was a statistically significant difference and association between the presence of *L.* spp. in air conditioning devices and employee absenteeism related to respiratory diseases in the facilities ($p<0.05$) (Table 2).

Table 2. *Association between the presence of L. spp. in air conditioning devices and employee absenteeism related to respiratory diseases (N = 38)*

Survey question and answers collected in the facilities			*L.* spp.		Total
			Not detected	Detected	
Pronounced employee absenteeism related to respiratory diseases	No	N	23	1	24
		%	76.7	12.5	63.2
	Moderate	N	3	3	6
		%	10.0	37.5	15.8
	Yes	N	4	4	8
		%	13.3	50.0	21.1
Total		N	30	8	38
		%	78.9	21.1	100.0

$\chi^2 = 11.176$; p = 0.004; Ledend: *L.* spp. - bacteria from the genus *Legionella;*

DISCUSSION

In this study, *L.* spp. was detected in the air conditioning devices of 8 (21.1%) facilities out of the total number of investigated air conditioning devices in 38 public facilities in the Sarajevo Canton. The prevalence of bacteria in the analyzed samples shows similar trends compared to the results of other relevant studies. For example, in a study conducted in Bosnia and Herzegovina, 238 water samples from different public water systems were analyzed, where *L.* spp. was isolated in 18.62% of samples from the water supply system and 8.82% of samples from cooling, heating

devices and fountains (28). The second study covered the testing of pool water in the area of Central Bosnia Canton on a small sample (N=13) and *L*. spp. was isolated in 4 (31%) samples (29). The results of our research can only be partially compared with a four-year study conducted in Canada, where *L*. spp. was detected in 48.7% of cooling towers (N=2852), an additional component of the air conditioning device that enables heat removal from the condenser (30). The difference can be explained by the methodological approach, since the mentioned study included several years of monitoring with repeated monthly sampling, which increased the probability of bacteria detection.

By comparing the collected survey responses regarding the management and facilities in which *L*. spp. was detected, mixed results were obtained, and it can be said that only there is impact of conducting internal employee training on the reduced colonization with *L*. spp. in air conditioning devices was established, the result of the statistical analysis showed that there is a statistically significant difference. The Water Management Program (WMP) was implemented within the health system in the state of Wisconsin, USA. The research focused on hospital and related facilities and investigated water systems including air-conditioning devices in order to reduce the risk of *L*. spp colonization. The WMP included staff education, monitoring, intervention measures and verification of effectiveness, which led during the four-year study to the reduction of positive findings from 11% to 3% of samples and the elimination of repeated positive findings (31). Also, research conducted in Primorsko-Goranska County (Croatia) in the period 2013-2019 showed an upward trend in the proportion of *Legionella pneumophila* positive samples (from 10.1% in 2016 to 24.4% in 2017, or 22.7% in 2018). After the implementation of a proactive program (systematic monitoring of water and cooling systems, implementation of technical disinfection measures, risk assessment, management guidance and staff education), in 2019, 17.9% of positive samples (85/475) were recorded, with no registered cases of LD (32). These findings indicate that systematic monitoring and organized management of water systems can contribute to reducing the risk of legionellosis. The results of our research showed a satisfactory level of knowledge regarding bacteria and risks to human health, a small coverage of facilities where external education is organized was recorded, while in 28 (73.7%) facilities a person was employed to supervise and monitor the operation of air conditioning devices, but no statistically significant difference between the two groups of investigated facilities was noted for any of the above questions. A correlation was established between the colonization of *L*. spp. in air conditioning devices and absenteeism of employees in the facility related to respiratory diseases, the result of the statistical analysis showed that there is a significant difference. It is considered that treatment of patients with Pontiac fever is not necessary (19). However, there is a possibility of a high risk of illness, or a high incidence of infection, for example, out of a total of 100 people exposed to *L*. spp. 95 may become ill (33), and this may directly lead to an increase in the rate of absenteeism in the working population, which further indicates a serious approach to preventive and control measures in the workplace. In addition to *L*. spp., previous research indicates the possibility of contamination of certain components of air conditioning devices with other pathogenic bacteria that can cause various respiratory problems (34, 35). The high frequency of symptoms of Sick Building Syndrome (SBS)

among employees indicates the impact of indoor air and air conditioning on health. A study among 615 respondents showed that 61% had respiratory symptoms, while in another study among 91 employees 93.4% experienced SBS symptoms, and it was found that air quality and poor ventilation may be associated with these symptoms (36, 37). In recent years, the relation of profession with LD has also been increasingly examined. Based on the results of a study conducted in Italy (2023), it was found that car wash workers are exposed to the higher risk of getting sick of legionellosis. Thirty car washes were examined, and 120 samples were analyzed, of which 10, or 8.3%, had isolated *L*. spp (38). A sporadic case of LD caused by *L*. ph. serogroup 1 was recorded in Croatia in a bus driver. The bacterium was isolated in water samples from a bus water tank and high concentrations were recorded. The driver used the water to wash his hands and face (39). Also, a study previously conducted in Turkey indicates that the profession of driver is at risk of contracting legionellosis, but in this case due to direct and prolonged exposure in an air-conditioning device, and no clear correlation was established (40). However, the findings of the study, which included the analysis of samples from air filters in cars, showed that *L*. ph. was isolated in a third of the analyzed samples (41). Filters, as an important component of air conditioning devices, require regular and professional maintenance, and perhaps contamination causes the risk of illness in bus drivers. Then, in addition to employees who work on the maintenance of large air conditioning systems (33) employees in recreation centers are also at risk of contracting LD (42), which was established much earlier. Analysis of previous research has shown that many professions are exposed to the risk of contracting legionellosis, however it is not classified as an occupational disease for all people, but for specific professions with a proven risk in many European countries it can be recognized as an occupational disease. For example, in Germany, infections caused by biological agents, including *L*. spp., are recognized as occupational diseases in employees exposed to risk in the workplace (43).

As research limitations we can note that the sample in this research was relatively small, which could be reflected in the reliability of the interpreted results. Also, this research was conducted once, which could have affected the prevalence of bacteria in air conditioning devices, considering the fact of the influence of seasonal variations on the colonization with *L*. spp. In addition, the accuracy of the data collected using the survey questionnaire was solely dependent on the honesty of the respondents, which suggests that the interpreted results should be interpreted cautiously.

CONCLUSION

The obtained results indicate the presence of *L*. spp. in air-conditioning systems of public facilities in the Canton of Sarajevo. It was found that internal staff training contributes to reducing the risk of bacterial colonization in air-conditioning systems. Additionally, the presence of bacterial colonization in these systems was associated with an increased risk of employee absenteeism. This study did not establish a statistically significant association between employees' level of knowledge about the bacterium and its potential health effects, nor between the presence of a person responsible for monitoring and maintaining air-conditioning systems and bacterial colonization. Furthermore, no effect of external training activities was confirmed, which were, in any case, rarely represented in

the surveyed facilities. The obtained results certainly indicate the importance of establishing a clearly defined regulatory framework, which should include, in addition to the control and monitoring of microbiological load in air conditioning devices, an assessment related to the exposure of employees and visitors in facilities. Additionally, it would be useful to conduct research on a larger sample with a special focus on examining shopping centers and the relation of certain occupations with the risk of legionellosis.

GENERATIVE AI STATEMENT

The corresponding author declared that generative AI was not used in the creation of this manuscript. The paper was prepared based on the authors' own research, professional knowledge, and relevant scientific literature, while respecting the principles of academic integrity and scientific ethics.

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LEGIONELLA SPP. U KLIMATIZACIJSKIM SISTEMIMA JAVNIH OBJEKATA U KANTONU SARAJEVO: ULOGA MENADŽMENTA I IZOSTANAK ZAPOSLENIKA

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SAŽETAK

Uvod: *Legionella spp*. su oportunističke patogene bakterije koje izazivaju dva oblika bolesti: teži, češće dijagnosticiran oblik – legionarsku bolest i blaži, rjeđe dijagnosticiran oblik – pontijačnu groznicu.

Ciljevi istraživanja: Osnovni cilj istraživanja bio je ispitati prisutnost *Legionella spp*. u klimatizacijskom uređajima istraživanih objekata.

Metode: Studija je provedena u Kantonu Sarajevo, Federacija Bosne i Hercegovine. Istraživanje je obuhvatilo uređaje za klimatizaciju u javnim objektima. Uzorkovanje je provedeno tokom dvogodišnjeg perioda. Prikupljeni su uzorci vode i uzorci uzeti metodom vlažnog brisa. Uzorci su laboratorijski analizirani na prisustvo *Legionella spp*. u skladu sa standardnom metodom. U periodu analize uzoraka laboratorija je bila u procesu akreditacije prema važećem standardu. Također je provedeno anketiranje u obuhvaćenim objektima.

Rezultati: *Legionella spp*. je detektirana u klimatizacijskim uređajima 8 (21%) objekata. Nije ustanovljena povezanost između znanja, eksternih edukacija i organizacije menadžmenta s kolonizacijom bakterije u klimatizacijskim uređajima. Interne edukacije zaposlenika provode se u tri (37,5%) objekta u odnosu na osam objekata u kojima je detektirana bakterija ($p < 0,05$), pored toga je detektirana u 4 (40,0%) objekta gdje su se izjasnili da je izražen apsentizam zaposlenika povezan s respiratornim oboljenjima ($p < 0,05$).

Zaključak: Rezultati naglašavaju potrebu za sistemskim pristupom upravljanju rizicima i unapređenjem praksi koje doprinose sigurnijem boravku korisnika i zaposlenika u klimatiziranom prostoru javnih objekata na području Kantona Sarajevo.

Ključne riječi: Bakterijska kolonizacija, edukacija, korisnici objekta, legionela, faktori rizika.

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