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ANALYSIS OF THE NOISE IMPACT IN URBAN AREA IN THE CITY OF SKOPJE

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ABSTRACT

Noise pollution in the urban environments is becoming increasingly common and it has potential to harmfully impact on people's health and decrease the overall productivity. Skopje, as the capital of North Macedonia, is a city that faces problem with the environmental noise, causing different forms of health problems. In this work, a methodology for choosing pilot area and analyzing the noise pollution in that area through objective and subjective analysis is presented. The chosen pilot area is a neighborhood located in the central part of the city, surrounded with four frequent streets and a lots of inhabitants and visitors. Measurement for the noise levels were carried out using 1st class hand-held device, from which the results indicated increased noise pollution. A general survey was applied to a sample of 96 inhabitants, employees and visitors in this pilot area. By analyzing both of the approaches for noise analysis, a correlation between them is found in order to find the most influential noise source. The most significant and annoying noise source is found to be the noise caused from traffic flow and vehicles and engines that drive at high speed.

KEYWORDS: environmental noise, subjective analysis, survey, noise measurements.

1. INTRODUCTION

Noise pollution is the third main reason of urban environmental pollution in Europe, responsible for harmful effects that are undesirable to the environment and the quality of life of the population [1]. According to the European Commission: "Environmental noise, caused by traffic, industrial and recreational activities is one of the main local environmental problems in Europe and the source of an increasing number of complaints from the public" [2]. Regarding to this, the noise pollution is a global problem all around the world, mainly caused by urban traffic [3, 4], considering as significant public health problem in the urban cities that leads to hearing loss, sleep disturbance, reduced productivity, increased drug use and traffic accidents [5]. The analyzes carried out in [6] confirm that at least 25% of the population living in Europe has a poor quality of life due to the environmental noise anomaly and that between 5% and 15% of the population suffers from a serious disturbance of sleep caused by noise. According to analysis conducted by the European Union in 32 countries on the noise impact on the health of the population, the results

show a disruption of the health with the occurrence of hypertension, cardiovascular disease and increased anxiety [7].

By measuring the noise level and analyzing the noise maps, studies in several countries have confirmed the increased noise exposure in urban areas [8, 9]. These studies present an essential tool for supplying relevant information for the urban noise pollution in order to accomplish global and local action plans. However, these studies only analyze the objective part of the noise, and not the effect that the noise causes on the population that live in urban areas.

In [10], an analysis of the subjective noise impact was conducted through a method of interviewing, highlighting the problems that arise due to the harmful effect, such as fatigue, depression, headache and reduced sleep quality. According to the conducted analysis of the subjective impact of noise, the authors in [11] present a model for the impact of the anxiety, depending on the noise exposure, taking into account the impact of the noise through day and night time period. Relation between annoyance and noise exposure from the transport such as aircraft, road traffic and railways is established. The subjective noise sensitivity of the urban population is a main factor when analyzing the critical and most influential noise sources.

In order to approach the problem with the noise pollution, both objective and subjective analysis can be performed. The objective analysis deals with the physical viewpoint of the sound analyzed as a sound wave, while the subjective study deals with the noise influence on the individual hearing and annoyance from the people. In [12], the environmental noise was described and analyzed in university campus based on noise measurements, noise mapping and interviewing. By analyzing the objective and subjective parts of the noise, a conclusion about the noise effects were established. The research shows that by applying the two approaches, significant and useful characterization of noise pollution can be achieved.

The city of Skopje faces an overcrowding, leading to rapidly developing and increasing infrastructure. Based on the by-laws and regulations, local action plans have to be done in every municipality. By conducting these action plans, noise measurements are carried out, showing increased noise level in the central urban areas. Also, subjective analysis for the noise impact in adult population is carried out in [13, 14], confirming that the noise in the urban environment causes anxiety, especially for the elder population in Skopje. The research shows that environmental noise is a significant hazard in urban environments, and assessment of

annoyance may prove a useful tool for town planners and public health policy makers.

Further detailed research is needed, where, through comparing the objective and subjective analysis, the definition of critical noise sources will be defined. In this paper, the measurements analysis for the noise level will be presented, followed by survey for the subjective noise sensitivity in a chosen pilot area. By applying these two approaches, correlation between them is established in order to better understand and characterize the urban noise pollution.

2. METHODOLOGY

2.1 Pilot area

The city of Skopje, as a capital city is divided into 10 municipalities, where the most visited area is the central municipality 'Center'. 'Center' has been selected as a representative area, which is constantly exposed to increased noise due to the high frequency of cars and the large number of bars and restaurants near residential buildings. The neighborhood named 'Debar Maalo' in the central municipality is an area of special interest, because it is surrounded by four main streets that have constant high flow of vehicles. This overpopulated residential area has five educational facilities and a lot of business facilities, and also has a lot of visitors because it is well-known for the various bars, restaurants and cafes. Increased flow of vehicles is noticed due to the excessive visiting population, the central location of the neighborhood and the boulevards around which connect different parts of the city.

By analyzing the monitored results from low-cost sensor network in the city of Skopje [15], it was concluded that the measuring station near the neighborhood of 'Debar Maalo' has the highest noise pollution in the last three years. The results are additional indicator that confirm that this area is constantly exposed to increased noise level.

To confirm and analyze the increased level of noise, noise measurements are carried out. Also, by carrying out a survey, a subjective analysis is done in order to establish correlation between the objective and subjective analysis.

2.2 Objective part

Six measuring points were selected as indicated in Figure 1.A., which were chosen based on the national by-law for defining the location of the measuring points [16]. Eighteen noise measurements were taken from Monday till Friday in three time periods: day, evening and night. The methodology for the noise measuring was according to the European Noise Directive END/2002/49/EC and the international standards which are transposed by the national by-laws, following the recommendations of Parts 1 and 2 of the ISO 1996 standard [17, 18]. The European standard specifies a minimum period of 5 minutes for the measurements, therefore the chosen measurement time was 10 minutes long for each measurement. The hand-held analyzer from Brüel & Kjær 2250 1st class was used for the measurements. Acoustic descriptor such as A-

weighted equivalent sound pressure levels (L_{eq}) were used and the results were expressed in $dB(A)$.

2.3 Subjective part

In order to determine how the noise influence on the inhabitants, a survey was conducted. Important parameters while creating the survey were defined, such as: number of respondents, the type and the method of conducting the survey.

Based on the formula for determine sample size from the Research division of the National Education Association [19], when calculating the number of respondents, the factors that depend on choosing the number of respondents were taken in consideration, such as: the total number of inhabitants, factor based on the degree of certainty, margin of error and proportion of population. According to the analysis, around 10000 inhabitants live in this area, which indicates 96 respondents to successfully conduct the noise impact survey.

The survey was conducted in standardized form, with questions and a choice of answers given in advance, according to a survey methodology for critical thinking approach [20]. The form is consisted of 10 questions, where the respondents can choose one or more answers. The purpose of the survey analysis is to obtain information on the impact of noise, its intensity during the day and year seasons, the sources of noise that most influence on the subjective feeling of the population and how noise affects health. The interviewing methodology was realized through interviewing the respondents from 15 years old and above, of the respondents living, working or visiting the chosen pilot area. In order to establish successful survey on the whole area, different locations for interviewing were chosen. Figure 1.B. presents graphical visualization of the location of the respondent, from where it can be concluded that the whole area was covered.

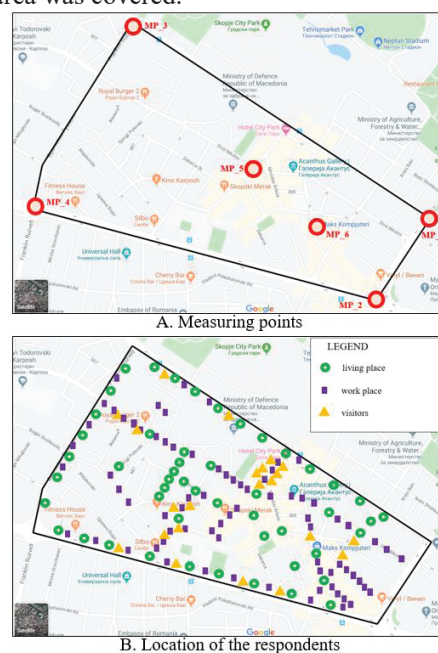


Figure 1. Chosen pilot area: 'Debar Maalo' neighborhood (A. Objective analysis, B. Subjective analysis)

3. RESULTS AND DISCUSSION

3.1 Objective part

The results from the noise measurement were compared with a limited values for the three time periods recommended by by-law for environmental noise limits in North Macedonia: $Leq=60$ dB(A) during day time from 07:00 till 19:00 o'clock; $Leq=60$ dB(A) during evening time from 19:00 till 23:00 and $Leq=55$ dB(A) during the night time from 23:00 till 07:00 o'clock. Table 1 shows the results from the noise measurements.

MEASURING POINTS	DAY dB(A)	EVENING dB(A)	NIGHT dB(A)
MP1	73.4 (+22.3%)	72 (+20%)	70.3 (+27.8%)
MP2	69.8 (+16.3%)	69.8 (+16.3%)	68.7 (+24.9%)
MP3	66.8 (+11.3%)	66.7 (+11.2%)	64.6 (+17.5%)
MP4	73.6 (+22.7%)	70.6 (+17.7%)	66.7 (+21.3%)
MP5	67.2 (+12%)	63.4 (+5.7%)	66.7 (+21.3%)
MP6	58.8 (-14.7%)	62.1 (+3.5%)	57.6 (+4.7%)
LIMIT VALUE	60 dB(A)	60 dB(A)	55 dB(A)

Table 1. Noise measurements results

The results from the measurements indicate that only one measurement out of 18 is under the permissible limited value. The other 17 measurements, i.e. 94.5% of the results showed increased noise level above the limited one. It can be concluded that the noise level in the chosen urban area is increased from 3.5% to 27.8% from the limited value.

3.2 Subjective part

After conducting the survey and processing the results, some conclusions were carried out. Figure 2 shows the general data for the respondents (their age group, gender and whether the pilot area is living, working or visiting place). It can be concluded that the most respondents (38%) are at age group between 45 to 59 years and for most of the respondents (55%) 'Debar Maalo' is work area.

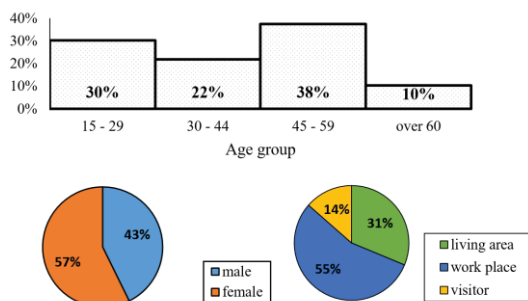


Figure 2. General information from the survey

Regarding the question of how much they are affected by environmental noise levels, most of the population are very concerned (59%), and they think that

noise is very important and serious problem that affects the population (Figure 3). From here, we can conclude that the noise is a serious problem that has to be further analyzed in order to solve and reduce the noise level.

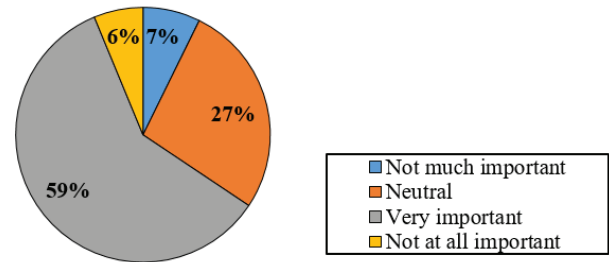


Figure 3. Level of influence of the environmental noise on the respondents (Responses to the question: 'How concerned are you with the level of environmental noise?')

According to Figure 4, noise has the highest intense during summer (76%) and spring time (56%). When answering this questions, some of the respondents further explained that during this time of year the noise has the highest intense due to the pleasant, warm weather and increased mobility of the population. In addition, to the question "at what time of day the noise has the most intense", 36% of the population responded the noise affects constantly and 28% at night. During night time people are more sensitive to noise, hence this leads to the high percentage of responses for high noise intensity during this time. Also, by analyzing the measurements from the objective analysis, the noise level is much higher during night time with increased level from 4.7% to 27.8%.

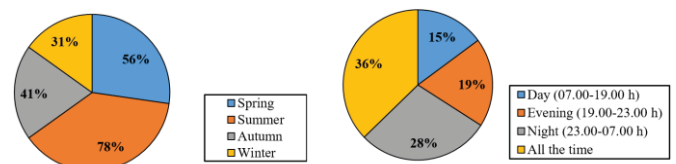


Figure 4. The highest noise intensity in the day and year

On the question 'How noise affects your health?' it has been reported that 41% of the population suffers from anxiety because of the noise, while 35% of the population suffers from disturbed sleep due to noise pollution. Noise does not cause any impact on 23% of the population health. In order to identify the most influential noise-causing sounds, the respondents were able to choose between multiple answers, as shown on Figure 5. When analyzing the answers, the results had shown that the noise caused by high-speed vehicles and motors is the dominant source that causes different forms of diseases, such as anxiety and disturbed sleep. The most disturbing sounds are the sounds caused by traffic, traffic congestion and fast driving of vehicles and engines.

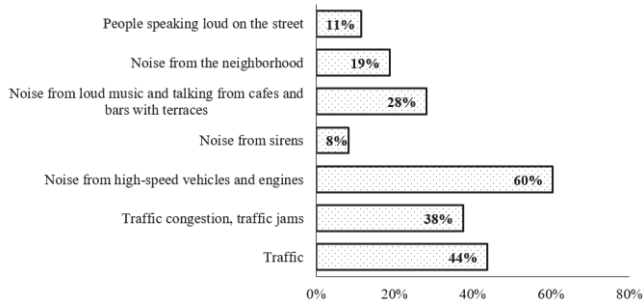


Figure 5. Most influential noise-causing sounds

The increased noise pollution is related to different sources and different causes for its occurrence. Figure 6 shows respondents' opinion on the possible causes of noise, where the main reason is found to be the non-compliance with legal obligations, unorganized city infrastructure, insufficient inspection control and low awareness among the population.

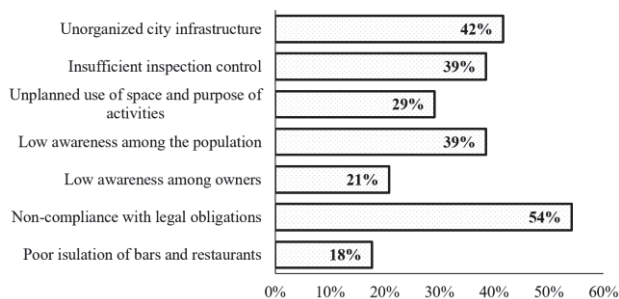


Figure 6. Possible reasons for noise pollution

According to the survey, it can be concluded that the major problem of the population in terms of noise in the chosen area is the noise generated by the traffic, i.e. the noise from high speed motors and vehicles.

3.3 Correlation between the objective and subjective part

From the objective part, it can be confirmed that the noise exposure exceeds the limited values, which indicates increased noise level. The subjective part shows that the noise affects the population, causing disturbing effects and concern. The most disturbing noise sources for the population is the noise caused from traffic. Due to this results, in [21] was confirmed that maximum values of the equivalent sound level for urban traffic noise occur for the frequency of 1000 Hz. By analyzing the frequency spectra in 1/3 octave band for each measurement, it can be concluded that 14 out of 18 measurements showed maximum value at the 1000 Hz frequency. Figure 7 shows one representative measurement that confirms the trend of the peak value at 1000 Hz in 1/3 octave band, indicating urban noise traffic. The other measurements had peak value at other frequencies which indicated mixed urban noise (noise from neighborhood, traffic noise, people talking on the street, loud music and talking from bars).

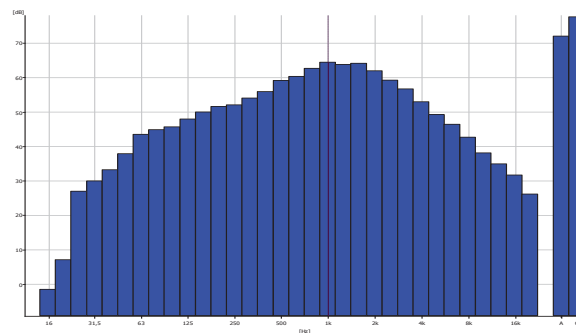


Figure 7. Frequency spectra in 1/3 octave band indicating urban traffic noise for one measurement

Generally, the peak when urban traffic noise is the main noise source is around 1000 Hz, essentially associated with tyre noise, while the lower frequencies tend to be associated with exhaust noise and higher frequencies tend to be associated with such instances as whine from a roof rack, as examined in [22, 23].

The frequency analysis from the objective part correlates with the respondents answers of the subjective questions (see Figure 5) posed in the surveys about the most disturbing noise sources. Based on the above analysis, it can be concluded that both, the noise measurements and sound perception surveys can be helpful in understanding the problem of noise pollution in urban areas, defining the main noise sources and thus improve the ability of city administration in dealing with this type of pollution. It is necessary to analyze both the perceptions of noise, objective and subjective, in order to define the critical sources of noise that cause harmful effects on the population.

4. CONCLUSIONS

The twenty-first century noise exposure is a major public health problem in the urban environment, requiring effective noise measurements and analysis for public health protection. The evidence for effects of environmental noise on health has the highest impact in annoyance, sleep and mental performance in the living organisms.

Objective perception, or noise level measurements in the area of interest had shown an increased level of noise. In order to do analysis from subjective point of view, a survey was conducted, showing that the population is disturbed by the increased noise levels. It can be concluded that the main problem for the population in terms of noise in the chosen area is the noise generated by the traffic, i.e. the noise from high speed motors and vehicles, which correlates with the noise measurements that show that the highest noise impact is from the traffic. There is a requirement for further research in this area, including more measurement points for higher granularity, real-time monitoring and additional detailed subjective analyses for the noise exposure.

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