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ORIGINAL ARTICLE

The Evaluation of Noise Pollution at Samen District in Mashhad, Khorasan Razavi Province, Iran using Geographic Information System

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ABSTRACT

Samen district is located in the city of Mashhad, Khorasan Razavi Province, Iran and is most famous for housing the shrine of Imam Reza. Every year, 32 million pilgrims visit the Imam Reza shrine from inside and outside the country. The question of noise pollution in this district, has been neglected compared to other forms of pollution. We investigated noise pollution using Geographic Information System (GIS) in this district. Equivalent sound level, sound pressure level, noise pollution level and traffic noise index, were measured in the summer and fall of 2016. The measurements were done using EPA guidelines and were analyzed. GIS was employed to prepare the zoning map of the measured equivalent sound level and maximum sound level. The values of equivalent sound level at all of the measured stations exceeded the noise pollution guidelines suggested by Iranian Environmental Protection Organization. The value of this parameter for 87.5% of stations was 75 dB in summer. The noise pollution level value in 78% stations was higher than 82 dB in summer, and the value of this parameter in fall for 75% stations was higher than 79 dB. This area is suffering from a high degree of noise pollution. Noise maps due to being able to detect peoples' habits of moving around the different parts of the city and at different times could facilitate computer-assisted control of the urban traffic.

KEYWORDS: *Environmental pollution, Geographic information systems, Spatial analysis, Transportation noise*

INTRODUCTION

One of the most important components of the assessment and management of noise pollution in urban environments is data collection in the form of an algorithm. The mapping of noise pollution is one of the most important tools of the study, for the diagnosis and control of noise pollution in the environment [1-3].

In most of the large countries of the world including Sweden [4], South Korea [5], China [6] and Japan [7], Geographic Information System (GIS) was used to evaluate noise pollution and noise mapping and the noise pollution in high-traffic areas of these cities was more than 70 dB.

Some cities of Iran including Tehran [8], Isfahan [9] and Yazd [10] have also embarked on noise map research. Based on GIS, this method has more ability than conventional methods in the analysis of environmental noise [11]. Pollution was evaluated based on GIS in Sweden. They used mathematical measures to obtain noise mapping of the large area such as SKANE and smaller areas in the city of Lund [4]. Moreover, noise pollution of roads traffic was evaluated using the GIS in Fukuma, Japan [7]. Fiedler and Zannin studied noise pollution indexes such as equivalent sound pressure level in a Latin American metropolis using GIS [12].

In order to prevent the effects of noise pollution and eliminate noise control plans in

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crowded and high traffic areas, and also find a better solution for the question of noise pollution, it appears that having noise maps that presented full information of noise parameters and changes of time and location in a crowded urban area, might be necessary for all cities including Mashhad.

Mashhad, with a population of over five million people due to its religious, economic, and industrial structure is considered the second biggest and most populated city after Tehran in Iran. Because of the existence of the shrine of Imam Reza (peace be upon him), Mashhad annually welcomes over 32 million pilgrims from inside and outside the country. Cars and transportation vehicles are the most important sources of noise pollution in Mashhad that also affect other areas nearby and since the question of noise pollution in Mashhad particularly in the district of Samen has been neglected, compared to other forms of pollution. Despite studies conducted in high traffic areas of Tehran [8] and other large cities in the field of noise pollution, until now, no comprehensive study has been conducted in this area, therefore the survey of this question in this district is necessary.

The aim of this study was evaluating of noise pollution by means of GIS in Samen district and the comparison to the existing standard.

MATERIALS AND METHODS

The Samen district with an area of 3370000 km2 is located in Mashhad City. The study location is selected due to its importance for housing the shrine of Imam Reza and high accumulation of commercial places and higher and significant traffic volumes in this district than other regions in Mashhad. Noise levels were studied in 24 stations in the morning, evening and night in interval periods of 8-10, 16-18 and 20-22 in the summer and fall of 2016. After determining the number of stations, selection of appropriate points at these stations was determined in a manner that has enough distribution in the study area. To determine the exact position of each station, Global Positioning System (GPS, Garmin Montana 650) was used.

The parameters used in this study include:

Leq: Equivalent sound level over a given period of time

SPL: Sound pressure level is the logarithm of the ratio of a measured sound pressure to the reference sound pressure level and is calculated using the following equation:

(Equation 1):

$$SPL = 20 \log (p/p_0)\ dB$$

Where p is the measured sound pressure and p_0 is the reference sound pressure

L10: L10 is the noise level exceeded for 10% of the time of the measurement duration

L50: L50 is the noise level exceeded for 50% of the time of the measurement duration

L90: L90 is the noise level exceeded for 90% of the time of the measurement duration

TNI: Traffic noise index indicates the equivalent sound level for continuous condition of public traffic and was calculated from the following equation [13]

(Equation 2):

$$TNI=4(L_{10}-L_{90}) + L_{90}-30\ (dB)$$

NPL (noise pollution level): According to U.S. Department of Housing and Urban Development, annoyance caused by exposure to noise, depends on the average sound level and variability of the noise sources calculated from the following equation [14]

(Equation 3):

$$NPL= Leq + (L_{10}-L_{90})\ (dB)$$

To evaluate the noise level, the sound level meter of B&K 2267 type in A weighted network and fast mode was used based on the standard recommended by EPA in 1999. To ensure the accuracy of the results, the sound level meter was calibrated before and after use employing a 4231 Bruel and Kjaer calibrator. In order to determine the standard condition, the measurement device was placed in free field situations in front of the receiver and the measurements were done in each station 1.5 m above ground level and 1 m beside the curbside streets [15]. Moreover, in order to protect the sensor of sound level meter, foam protector was used. This foam protector minimizes the impact of air flow.

Noise mapping method: After evaluating different interpolation methods, IDW method was selected. IDW is one of the most commonly used interpolation techniques [16]. IDW has higher accuracy than other interpolation methods [2]. In IDW, more distant points had less importance by weighting each point by the inverse of the distance [17]. In other words, in IDW as a point based and typical local interpolation algorithm, each measurement is assigned to the reference point after weighting by the inverse of the distance [2,18]. For interpolation, we used the formula that takes the inverse of the distance raised to the 2nd power which is the default in the ArcGIS and is most commonly used [16]. IDW can be represented by the following equation:

(Equation 4):

$$Z = \frac{\sum_{i=1}^{n} w_i Z_i}{\sum_{i=1}^{n} w_i} = \frac{\sum_{i=1}^{n} Z_i / D_i^p}{\sum_{i=1}^{n} 1/D_i^P}$$

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where Z is the interpolated value for a point with an unknown observed value, w_i is the weighting function that determines the relative importance of each individual control point Z_i in the interpolation procedure, Z_i is the observed value at control point i ($i=1,\ldots,n$), which is in the closest neighborhood of the interpolated point, and n is the total number of such points that are used in the interpolation [17-19].

RESULTS

The location of the study and noise measurement stations are presented in Figure 1.

Figure 2 and 3 show a few examples of maps of Leq and Lmax in summer and fall. Maximum value of this parameter in the summer is related to Baitul Muqaddas square with 80.8 dB and in the fall is related to Tabarsi square with 76.9 dB. The value of this parameter for 87.5% of stations was 75 dB.

In order to determine parameters of NPL and TNI, statistical levels (Lx: L10, L90) were used. Based on the measurement, the value of NPL and TNI in 78 and 80% at the measured stations were higher than 82 and 79 dB, respectively. The results of mentioned parameters in three high traffic stations are shown in Tables 1 to 3.

Moreover, these tables show SPL in three high traffic stations in summer and fall in three times (morning, evening and night). The maximum SPL values were 89.7 dB in the night shift of the summer in Baitul Muqaddas square. In addition, maximum values of this parameter were obtained in the fall with 82.2 dB at the morning shift in Shohada crossroad and Tabarsi square.

Table 1. The values of NPL, TNI, and SPL (dB) at Baitul Muqaddas square

Time	NPL		TNI		SPL	
	Summer	Fall	Summer	Fall	Summer	Fall
Morning	89.6	85.3	78.3	83.9	84.6	81.3
Evening	85.3	85.6	82.1	76.8	85.8	80.0
Night	89.8	84.8	89.1	73.7	89.7	78.6

Table 2. The values of NPL and TNI and SPL (dB) at Tabarsi square

Time	NPL		TNI		SPL	
	Summer	Fall	Summer	Fall	Summer	Fall
Morning	89.2	81.4	82.2	65.8	87.4	82.2
Evening	88.4	85.7	81.4	63	87.3	77.5
Night	87.8	82.2	80.1	79.1	89.5	80.2

Table 3. The values of NPL, TNI, and SPL (dB) at Shohada Crossroad

Time	NPL		TNI		SPL	
	Summer	Fall	Summer	Fall	Summer	Fall
Morning	88.1	84.1	83.5	80.0	85.7	82.2
Evening	86.3	85.7	82.4	65.5	88.5	77.7
Night	84.8	76.8	81.8	62.0	89.0	76.0

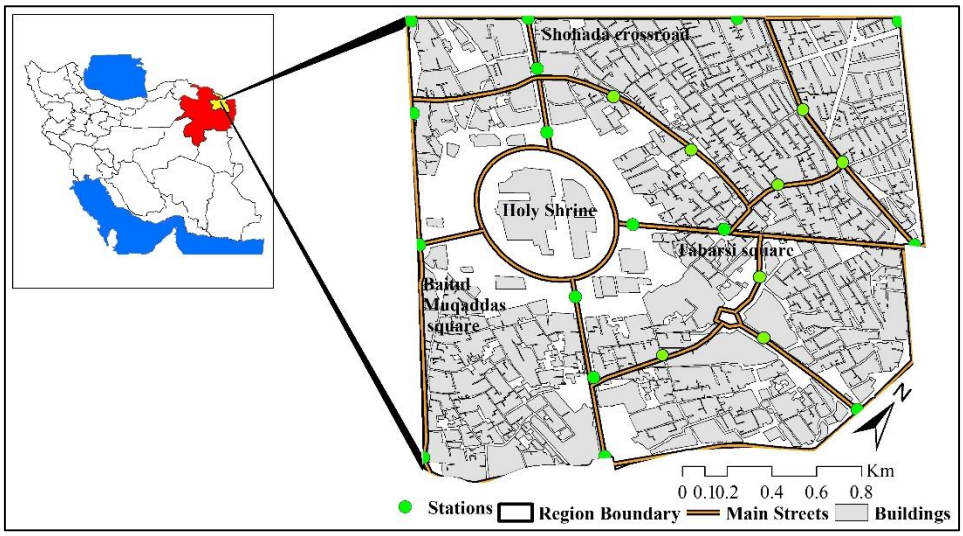

***Fig*. 1.** The location of the study and noise measurement stations

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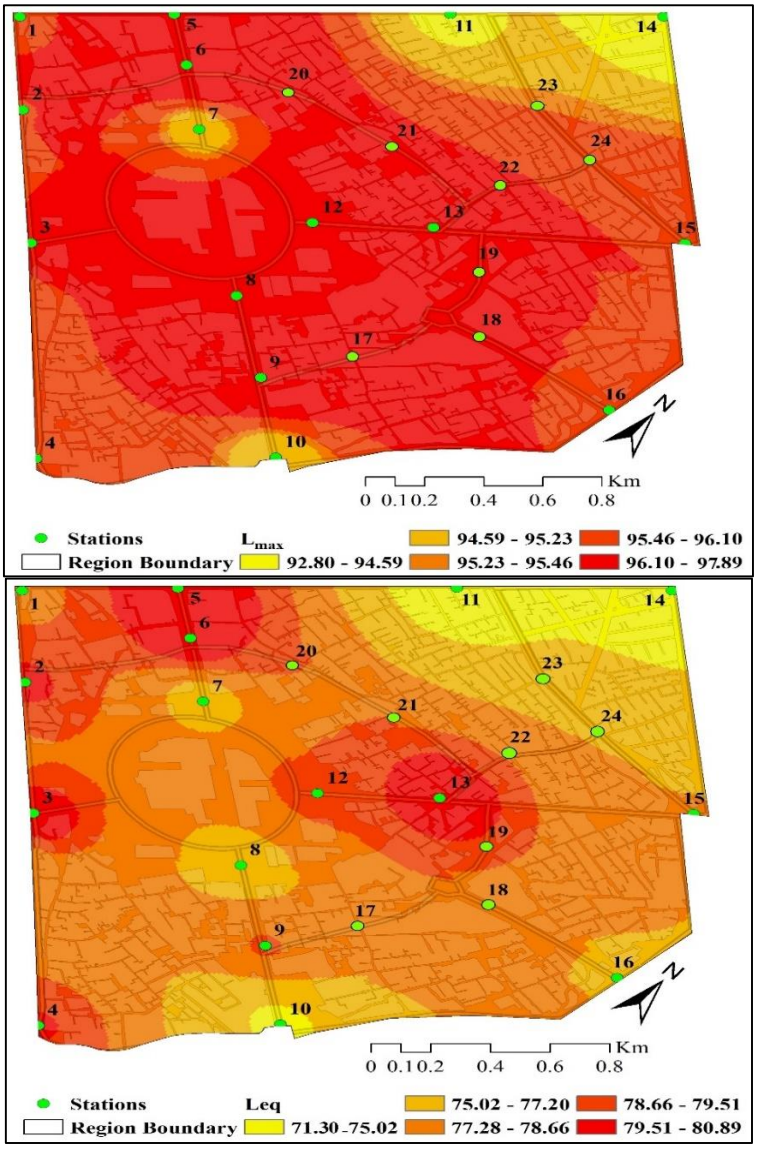

***Fig.* 2.** Spacial distribution of L_{eq} and L_{max} in summer at Samen district

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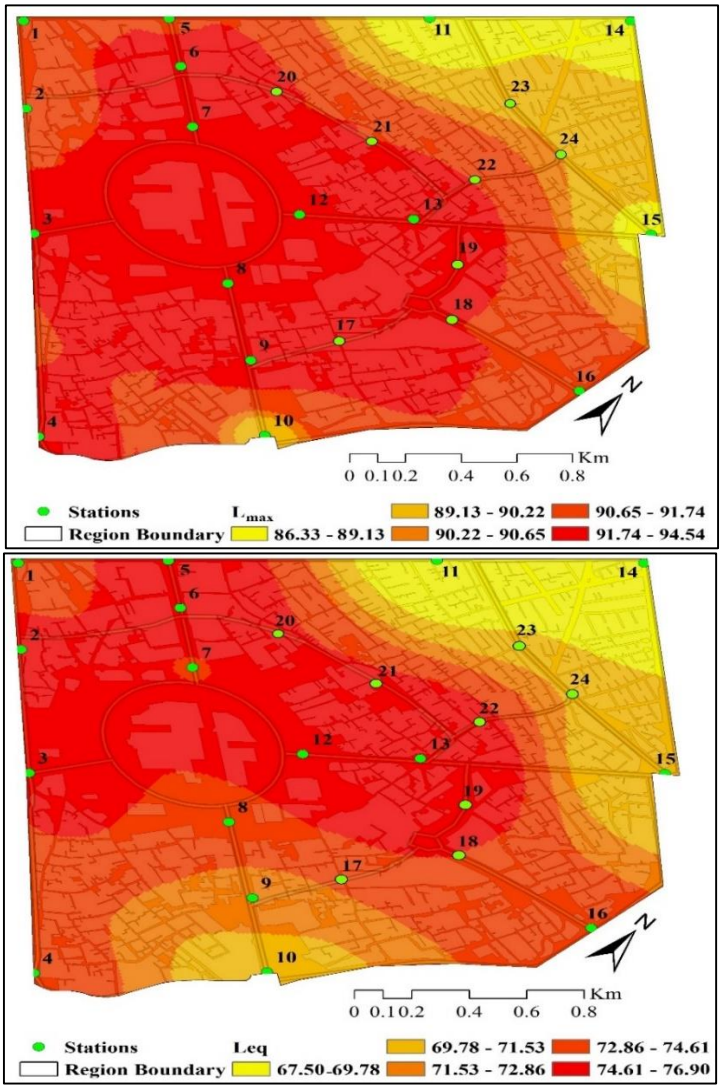

***Fig*. 3.** Spacial distribution of L_{eq} and L_{max} in fall at Samen district

DISCUSSION

According to the maps, in both summer and fall, the maximum value of Leq can be seen in the central part of the study area, due to further accumulation of commercial buildings and hotels and proximity to the holy shrine. Moreover, based on the measured values, the maximum Leq, in summer, is related to the Baitul Muqaddas square with 80.8 dB (night) and in the fall, these values have been reported in the Tabarsi square with 76.9 dB (evening). In both cases, the equivalent sound levels in the stated stations compared with noise guidelines suggested by Iranian Environmental Protection Organization for residential and commercial areas (60 dB) were 20.8 and 16.9 dB higher, respectively.

Leq was measured in Karachi, Pakistan. The average value of Leq was 66 dB, less than the mean value of Leq in Samen district with 77.1 dB [20]. In addition, equivalent noise traffic level was evaluated in Hamedan main roads. The average Leq value was obtained as 69.4 dB, less than the mean value of 77.1 and 72.3 dB in summer and fall at Samen district, respectively [21].

The results of noise pollution study in one of the cities of Brazil revealed that the equivalent sound level in 93.3% of cases has been more than 65 dB and has been more than 70 dB in 40.3% of cases [22]. However, in the Samen district, the equivalent sound level in 87.5% cases was higher than 75 dB. In another study, noise pollution was evaluated in Ghazvin City. The equivalent noise level in different areas was variable between 69.9 to 72.8 dB such that in 90% of the total time of measurement, Leq was higher than the limits recommended for residential and commercial areas [23].

Analysis of noise mappings of Leq reveals

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that the value of this parameter in stations No. 7 and 8 due to the existence of an underpass decreased up to 5 to 6 dB, compared with the high-traffic stations in the central part of the study area. Moreover, the value of this parameter in both summer and fall can be seen with a decreasing trend in the northwest corner of the study area due to the expansion of subway lines.

Generally, noise maps analysis of Leq in summer and fall shows that in all shifts, the values of these parameter in the summer has been considerably higher due to the dramatic increase in passengers and vehicles. In accordance with one-sample t-test, there is a significant difference between the Leq in summer and fall with the standard values ($P<0.05$) and the equivalent sound level at all times in summer and fall has been higher than the standard values.

The maximum value of NPL in the summer is related to Baitul Muqaddas square. Moreover, maximum value of this parameter in the fall can be seen in Shohada crossroad and Tabarsi square. This parameter has considered the changes in sound signals and shows the noise pollution of the environment in terms of psychological harassment and abuse, that has been recorded in the summer at Baitul Muqaddas square with 89.8 dB (night) and in the fall at Tabarsi square and Shohada crossroad with 85.7 dB (evening).

Shohada crossroad, due to the location of holy shrine nearby and on the other hand, due to the street leading to the Imam Reza terminal, in most cases, has gotten the highest values of the parameters measured in both summer and fall seasons. In addition, these high values at Tabarsi square can be attributed to the old structure of this area and streets leading to the railway station that increases the traffic in this area.

Most of the TNI values which indicate the impact of changes in traffic flow is related to Baitul Muqaddas square (89.1 dB) in the summer. This square is one of the main squares of Samen district and due to the high concentration of hotels and inns in this area, it has more traffic than any other measurement stations and the values of all parameters in this square, in most cases has been recorded more than all other stations.

A study was performed in Ilorin metropolis, Nigeria and the results showed that the highest values of NPL and TNI were 122 and 106 dB, respectively [24]. A study was conducted in crowded areas of Isfahan and found that the highest value of TNI with 82.5 dB was lower than Samen area with 89.3 dB [9].

In this study, the highest SPL and Lmax was related to the Imam Reza Street where Imam Mosa-Ebne-jafar hospital of Mashhad is located (Station No.3). Therefore, the movement of ambulances and visitors to this treatment center can be considered as an aggravating factor for traffic loads and noise pollution across this street. The high noise pollution levels around the hospital area could have a significant role in public health; this result is highly significant.

The value of SPL obtained in high traffic stations at night shifts of summer was more than fall, which could be due to the climatic characteristics of Mashhad, its dry and desert like atmosphere and residents' tendency to travel late in the day due to coolness of the weather. But the value of this parameter in fall during the morning was reported to be higher than that in the evening and night. The sound pressure level (SPL) was evaluated in Bukit Mertajam, Malaysia and Erbil city, Iraq. The value of this parameter was higher during evening and morning, respectively [25].

Due to the importance of environmental health factors, noise maps have been studied in many projects. Amongst these projects, a study like our study used the GIS software and IDM method in order to investigate noise pollution caused by traffic in SKANE area of Sweden. However, the difference was that Fracas in his study did not mention the selection of appropriate methods for interpolation and enjoyed the use of computational software that could present a predictive model for the distribution of sound in the mentioned region [4]. However, in our study, the best interpolation method after evaluation of optimal error was selected. The values of Leq, NPL, TNI was measured in District 14 of Tehran and IDW interpolation method was employed to prepare zoning maps, like our study [26].

CONCLUSION

The values of Leq in all measured stations were higher than the guideline values. Noise pollution in the Samen district has been a serious issue. It is due to the population growth in Mashhad and it exposes many citizens and pilgrims to high health risks. Thus a reform in the traffic management system and the implementation of traffic plans and creating restrictions is one of the most important and practical measures to control noise pollution. Other initiatives to reduce noise pollution in the studied district could include the expansion of the subway lines in this district and moving of the shopping and business centers outside the district of Samen.

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