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# Monitoring and measuring noise pollution in urban environments (Case study: Khorramabad city)

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**ABSTRACT**

**Introduction:** Environmental noise, caused by traffic, leads to increased risk of health problems. Nowadays, noise pollution is one of the most important problems in the communities which adversely affects the health. The aim of this study was to assess the noise pollution in Khorramabad city.

**Materials and methods:** To measure the noise level in the city, 39 stations near to sensitive places such as hospitals, educational centers, and so on were selected. Measurements were performed, for 30 min, in the mornings (7-10 AM) and evenings (5-8 PM) using a standard sound level meter. The measurements were made on working days during the week and assuming the traffic load was the same.

**Results:** The sound level in all 39 considered stations was higher than the standard of residential-commercial in more than 90% of the stations compared to the environmental standard. The mean of sound measured in the monitored stations was equal to 68.28±2.6 dB. The maximum measured sound level belonged to station S2. In station S2, the maximum measured sound was reported as 81.72±11.3 dB. The findings showed that sound level in the evenings were slightly higher than the mornings. Also, in the evening, the highest and lowest measured sound values belonged to stations S1 and S20. The amount of measured sound level at stations S1 and S20 was equal to 80.9 and 39.7 dB, respectively. Based on findings, the highest and lowest sound recorded belonged to stations S39 and S20 which area type of stations S20 and S39 was commercial and residential, respectively.

**Conclusion:** This study showed that the average level of sound pressure was higher than the permissible limit, so the necessity of planning is suggested to reduce the level of noise pollution and consequently reduce the anxiety level of citizens and increase health.

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## Introduction

Noise is defined as an irregular wave which is unpleasant, unwanted, and generally unavoidable. Noise pollution is a type of environmental problems which threatens the human health and the other living organisms. Noise is one of the main disturbing factors that not only adversely affects the hearing system, but also lead to mental disorders such as irritability, anger, and boredom. The resulting physical and mental problems will both negatively affect a person's lifestyle and work. Exposure to loud noise for a few seconds to a few hours may cause a temporary decrease in sensorineural hearing loss, which often returns within 24 h. Permanent Threshold change (PTS) may occur if calls are repeated with sounds that initially only caused TTS, which is commonly seen in employees who work with very loud noises [1]. Urban traffic is a major cause of air and noise pollution. Noise pollution is one of the urban problems of citizens, which is a growing problem and has potential effects on public health. Noise of public transport in cities and residential areas is one of these problems [2]. Waves which are inadvertently emitted into the environment and can be annoying to the hearing are called noise or noise pollution [3]. Noise is one of the physical factors which is the result of population growth, urban growth and development, industrial growth, expansion and widespread use of tools and machinery and equipment and increasing the number of vehicles [4]. Road traffic, noise from televisions, housing, noise from cell phones indoors, noise from airplanes, city and intercity trains, air conditioners, exhaust, electricity, and car and motorcycle alarms are examples [5, 6]. Noise pollution is dangerous to the public health of the community and also damages the environmental ecology. Therefore, intermittent control is necessary both to limit the pollution from the source and to reduce its subsequent effects [7]. According to the World Health Organization, today noise pollution is one of the most dangerous types of pollution (air-water and noise) and this organization has made a wide and widespread effort to educate the people of the world about the consequences and dangers of noise pollution [8].

The harmful effects of noise pollution on humans do not appear more directly and in the short term. Sound has a short-term decline and thus cannot remain in the environment for a long time, but this short-term durability has a significant long-term impact on humans and the environment. The physiological and psychological effects of sound on humans often appear gradually and in the long run have a devastating effect on human health. The psychological effects of noise are not directly related to the intensity of sound, because sometimes the slightest sound may cause the strongest reaction or the loudest sound may not affect the human mind. The psychological effects of noise vary by person, situation and time [9].

The human body's response to loud noise is similar to that of an imminent danger, such as the release of the hormone adrenaline, changes in heart rate, and blood pressure. Other problems with noise pollution include hearing loss, sleep disturbances, high blood pressure, extreme tiredness, indigestion, and depression [10].

Noise pollution has been extensively researched as a serious health and even safety risk factor in the world. Today, excessive noise in schools, offices, hospitals, public buildings and industries, annoys residents and employees, and the need to examine its quantity and quality in public places is even more important [11]. In order to prevent these effects and implement control-oriented plans in cities, standards for the amount of noise allowed in different urban areas have been developed by reputable organizations and scientific associations [12]. Advances in technology and the development of technology along with the growth of urban population have always had positive consequences for public welfare, but its negative effects based on the spread of various environmental noise pollution, such as noise pollution cannot be easily ignored [13]. Sources of noise pollution in urban areas can be divided into two groups: fixed sources and mobile sources. Fixed resources include industrial, construction and demolition, commercial, local, and recreational. Movable resources include land and air transportation. In urban areas, the engine and exhaust system of cars, light trucks, buses, and motorcycles is an important source of noise pollution which has a major environmental impact [14]. Measuring urban areas will be a prelude to identifying high-risk areas, control priorities, and predicting the outcome of control measures, and, therefore, relevant measurements at regular intervals are essential. If this measurement is especially combined with new technologies such as Geographic Information System (GIS), it can provide useful information in the field of risk identification and control. GIS is used in a variety of fields, including urban and regional planning, geology, agricultural mining, natural resources, and the environment, and can improve management and planning. Using this system, in addition to profitability, can speed up the planning process for diagnosing critical cases, and so on [15, 16]. Khorramabad city, the capital of Lorestan province, according to the population estimate in 2012, has a population of 5590-3 people, has 3 urban areas and is located in the north-south corridor of the country. This issue has caused a large volume of vehicles to pass through the crossing and communication line which passes through the city of Khorramabad and causes the spread of all kinds of pollution, especially noise pollution. During the last decade, the city of Khorramabad has grown rapidly in terms of population, size and establishment of industries and workshops, all of which have been effective in raising the noise levels in different areas of the city. According to the investigations, the causes of noise pollution in Khorramabad city are due to two main natural and social phenomena. The natural phenomenon which creates such a situation is that the city is located in a valley and surrounded by mountains. This problem has caused the northern part of the city to have a mountainous and uneven landscape, and the southern part to have an almost plain view, and the difference in slope can be seen in many parts of the city. This phenomenon causes noise pollution especially in streets which are devoid of greenery and have a steep slope. Because the cars which are moving from south to north put more pressure on the engine due to the use of heavy gears and these cars produce more noise. Also, the cars which are moving from north to south (downhill) increase the speed of the car, and again, they make more noise due to the fast movement of the wheels and the greater acceleration of the car's weight. In the first case, the noise pollution is caused by the wheels, which anyway, the noise pollution in the first case is more than the second case. In addition, the mountainous nature of the city also affects the increase in noise pollution in the city. The noise pollutants in Khorramabad city are: Heavy vehicles, cars, motorcycles, car sirens, drilling operations and urban development, crowd noise in alleys and streets, workshops and industrial centers, it is worth mentioning that the construction materials used in Khorramabad city are mostly cement and compacted bricks. Due to the importance of monitoring and analyze the noise pollution of the cities, as mentioned, urban noise pollution has increased the risk of public health, this study was to determine noise pollution and study the zoning in the city of Khorramabad.

## Materials and methods

### *Study type and sampling*

This is a descriptive cross-sectional study which was conducted in 2020 in Khorramabad. Places sensitive to noise pollution in Khorramabad include hospitals, clinics, educational facilities, schools, and kindergartens. According to studies conducted by other researchers and the use of the following relationships, the sample size was estimated (N=39×3×7=819).

### *Execution method (Research and data collection method)*

In this study, to investigate the amount of noise pollution in 39 stations mentioned, which using the comprehensive map of Khorramabad city has turned the city into a square with dimensions of 1.5×1.5 km (map number one), sampling of each of the squares. The measurement of acoustic parameters was performed in 2 shifts during the day (morning 7-10 AM and afternoon 5-8 PM) in autumn. The measurements were made on working days during the week and assuming the traffic load was the same. Sampling was done in each station on the sampling day with three repetitions, and on the holiday (Friday) 6 Fridays for six sampling stations. Sampling was done at any point according to the Iranian standard (standard of the environmental protection organization) for 30 min. Fig. 1 shows the sampling points. Sound pressure measurement, TES 1358 sound level meter, manufactured by TES Taiwan, was used with calibration of 94 dB and 114 dB at 1 KHz. In all stages of measurement, the sound level meter was placed on a three pedestal with a height of 1.5 meters. A sponge was used to place it on the microphone of the audiometer, which was used to prevent the error caused by the noise caused by the vibration of air molecules. Also, according to the ISO 1996 sound standard, the device was placed at a distance of 3.5 m from concrete buildings and walls that reflect sound [17, 18]. In this measurement, the device was adjusted based on the weight frequency A, because our goal was to estimate the amount of noise that people face in different areas and was, also, adjusted based on the weight time F and the minimum sound level ($L_{min}$), the maximum sound level ($L_{max}$) and sound equivalent level (leq) were measured [18]. Preparation of noise pollution zoning map through the master plan and detailed layout of the dwg extension maps, it classified the project layers in Autocad software and import them into Arcgis software. In Arcgis software, it first separate the desired layers from the rest of the dwg map layers and convert them to a geographical format (point, line, and polygon), or, more technically, apply the GIS ready operation. After creating the desired shapefiles, it enter the dot feature called the sound measuring stations into Google earth software. Then, it start locating the stations and creating a dot layer in Google earth software. Insert the problem created in Google earth software into Arcgis software and turn it into a shapefile. It place the point feature (sound measuring stations) on the land use polygon feature (which obtained through a comprehensive and detailed plan). Then, it generate the zoning map through IDW, Inverse distance weighted, interpolation. IDW method, First, in the input point features section, enter the complication of sound stations, and after determining the location of the zoning storage, the operation of creating the zoning map begins. After creating the zoning map, it specify the minimum and maximum volume through the symbology tab. Then, it prepare the desired drawings in the software layout of the software [19].

### *Statistical analysis*

How to analyze information and statistical methods used the studied indices were analyzed using kruskal-wallis statistical test and paired t-test to compare the index among the stations and one way ANOVA test to compare LAeq for morning and noon shifts in SPSS.

### *QA/QC*

This model measures the sound of the environment and analyzes the sound received from the environment. It has a measurement range 30 dB to 130 dB. The measurement ranges of this model are Lmin, Lmax, LE, Leq, Lp. It has the ability to measure frequency in classes A, C, Z. Also, The bandwidth range is 12.5Hz to 20KHz.

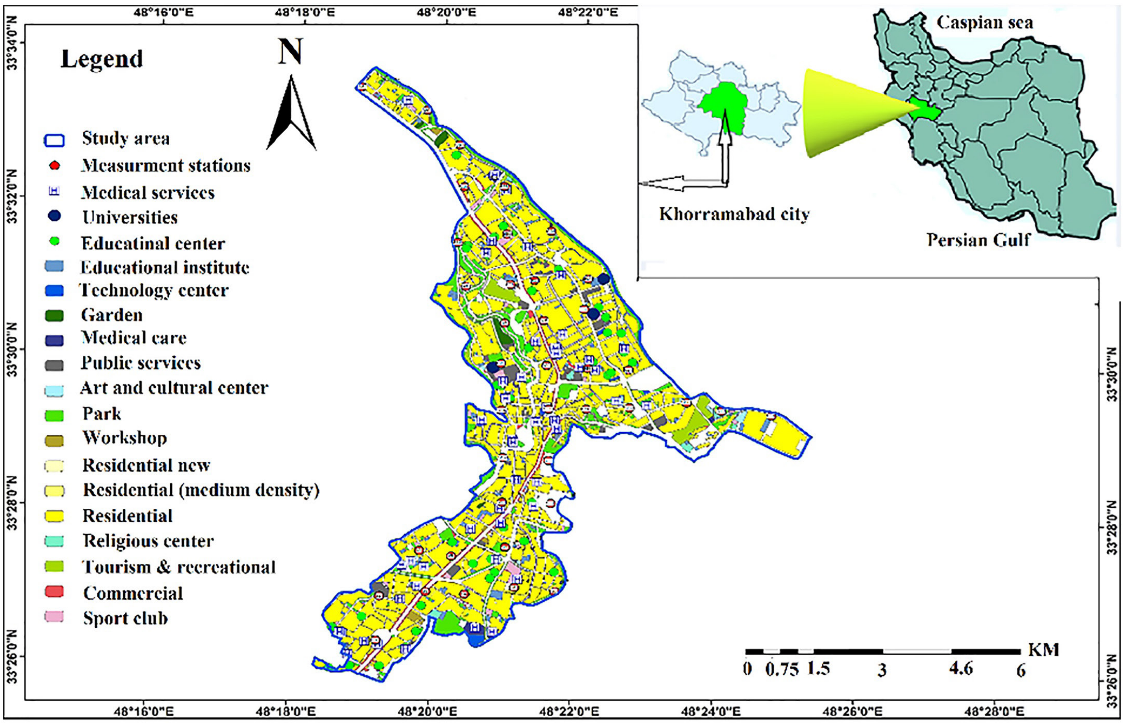


Fig. 1. The location of Khorramabad city in Iran and the selected sampling sites

Table 1. Sampling points in the study area

| Code | Name | Code | Name | Code | Name | Code | Name |
|---|---|---|---|---|---|---|---|
| S1 | Masoor | S11 | Ghazi Abad | S21 | Takhri Varzeshgah | S31 | Zagrosh st. |
| S2 | Shahrak Hekmat | S12 | Behesht park | S22 | Sattarkhan squre | S32 | Shahrdari |
| S3 | Serah Goldasht | S13 | Shariati | S23 | Shafa Hospital | S33 | Bostan 1 |
| S4 | Tamin Ejtemaai Hospital | S14 | 17 shahrivar st. | S24 | Basij Koy | S34 | Damavand 3 |
| S5 | East Goldasht | S15 | Esatern shohada | S25 | Q park | S35 | Tosca St. |
| S6 | Poshteh Hosseinabad | S16 | Korosh | S26 | Engelab st. | S36 | Abshar park |
| S7 | West Goldasht | S17 | Water palnt | S27 | Dntal Collage | S37 | Parsiloon |
| S8 | Baharestan near West Goldasht | S18 | Maskan Mehre st. | S28 | Khaydaloo 6 st. | S38 | Farhangiyan |
| S9 | Karim Khan Square | S19 | Kamalvand | S29 | Laleh Hall | S39 | Entrance to the city |
| S10 | Shaghayegh | S20 | Emam Reaz Mehre | S30 | Art 8 st. | | |

## Results and discussion

### *Descriptive statistics related to sound parameters in sound measurement stations*

Noise pollution is one of the most important environmental problems in cities, which endangers human health in different dimensions [20]. Noise pollution is the most important factor which disturbs the quality of the environment and environmental health in the city center [21].. Therefore, its continuous monitoring is an important issue in urban environments. The main purpose of this study was to draw the attention of city officials and decision-makers to this issue in case the noise exceeds the range of standards established for the country (Iran) and to confirm the presence of pollution, so that the researchers can conduct and encourage additional studies and prepare a sound map. In the present study, the sound level in all 39 considered stations was higher than the standard of residential-commercial in more than 90% of the stations compared to the environmental standard. According to the Iranian standard, it is 55 dB and 45 dB for residential areas during the day and night, respectively. It is 60 and 50 dB for commercial residential areas during the day and night, respectively. Therefore, only in less than 10% of the monitored stations, it was within the acceptable range. The results of the sound level measured at different stations are presented in Table 2. The mean of sound measured in the monitored stations was equal to 68.28±2.6 dB. The maximum measured sound level belonged to station S2. In station S2, the maximum measured sound was reported as 81.72±11.3 dB. The main reason for the higher noise level measured at this station can be attributed to the commercial nature of the area, which plays a large role in noise pollution. Station S2, with its significant population and dense residential structure, as well as busy streets and the existence of worn-out street asphalt, is a witness to the problems of noise pollution, which is tangible even for careless citizens. The minimum measured sound level belonged to station S20. In station S20, the minimum measured sound level was reported as 43.56±0.51 dB. Based in Table 2, the main reason for the lower sound level measured at this station can be attributed to the fact that the area is completely residential, which does not play a large role in noise pollution.

Table 2. Sound levels in different sampling stations

| Measuring Station | Maximum instantaneous sound level ($L_{max}$) | Minimum instantaneous sound level ($L_{min}$) | Maximum sound level equalent ($Leq_{max}$) | Mainimum sound level equalent ($Leq_{min}$) | Variation range of sound level equalent ($L_{eq}$) | Average sound level equalent ($L_{eq}$) | SD(±) |
|---|---|---|---|---|---|---|---|
| S1 | 86.20 | 70.60 | 80.90 | 73.20 | 7.70 | 75.90 | 3.40 |
| S2 | 82.80 | 8.65 | 5.77 | 1.69 | 4.80 | 81.72 | 11.30 |
| S3 | 79.90 | 60.20 | 73.70 | 70.00 | 3.70 | 72.08 | 1.40 |
| S4 | 75.90 | 59.00 | 71.70 | 62.50 | 9.20 | 66.53 | 3.15 |
| S5 | 79.80 | 68.50 | 76.40 | 64.20 | 12.20 | 70.51 | 4.81 |
| S6 | 83.80 | 60.80 | 72.10 | 69.20 | 2.90 | 70.61 | 1.16 |
| S7 | 75.50 | 64.40 | 71.50 | 68.60 | 2.90 | 69.60 | 1.005 |
| S8 | 83.20 | 67.00 | 75.80 | 68.00 | 7.80 | 70.80 | 2.81 |
| S9 | 82.40 | 62.00 | 76.70 | 66.30 | 10.40 | 70.95 | 3.80 |
| S10 | 88.30 | 67.20 | 79.30 | 74.30 | 5.00 | 75.93 | 1.82 |
| S11 | 85.20 | 64.00 | 73.90 | 71.10 | 2.80 | 72.53 | 1.19 |
| S12 | 78.70 | 68.50 | 75.30 | 73.00 | 2.30 | 74.05 | 0.75 |
| S13 | 82.30 | 68.60 | 74.80 | 72.30 | 2.50 | 73.15 | 1.009 |
| S14 | 86.20 | 58.90 | 75.80 | 73.00 | 2.80 | 74.61 | 0.94 |
| S15 | 85.40 | 60.50 | 72.00 | 68.50 | 3.50 | 70.20 | 1.25 |
| S16 | 84.40 | 63.70 | 74.60 | 68.80 | 5.80 | 72.16 | 1.93 |
| S17 | 86.30 | 64.20 | 76.60 | 70.20 | 6.40 | 72.75 | 2.68 |
| S18 | 65.40 | 40.70 | 56.10 | 41.50 | 14.60 | 48.31 | 5.80 |
| S19 | 71.20 | 36.20 | 63.30 | 39.70 | 23.60 | 50.05 | 9.07 |

Table 2. (Continued)

| Measuring Station | Maximum instantaneous sound level ($L_{max}$) | Minimum instantaneous sound level ($L_{min}$) | Maximum sound level equalent ($Leq_{max}$) | Mainimum sound level equalent ($Leq_{min}$) | Variation range of sound level equalent ($L_{eq}$) | Average sound level equalent ($L_{eq}$) | SD(±) |
|---|---|---|---|---|---|---|---|
| S20 | 56.40 | 38.40 | 48.10 | 39.70 | 8.40 | 43.56 | 3.88 |
| S21 | 76.20 | 54.70 | 71.10 | 68.50 | 2.60 | 70.00 | 1.03 |
| S22 | 77.90 | 63.20 | 72.30 | 65.50 | 6.80 | 69.06 | 2.22 |
| S23 | 83.40 | 63.80 | 73.20 | 69.70 | 3.50 | 71.53 | 1.40 |
| S24 | 79.70 | 62.80 | 69.60 | 67.50 | 2.10 | 68.75 | 0.73 |
| S25 | 78.70 | 66.90 | 75.30 | 73.00 | 2.30 | 74.05 | 0.75 |
| S26 | 87.70 | 63.70 | 76.30 | 68.50 | 7.80 | 71.66 | 2.76 |
| S27 | 80.20 | 63.00 | 73.20 | 67.70 | 5.50 | 70.43 | 1.88 |
| S28 | 80.50 | 51.00 | 69.90 | 61.30 | 8.60 | 64.33 | 3.40 |
| S29 | 62.00 | 48.20 | 55.00 | 51.10 | 3.90 | 52.58 | 1.58 |
| S30 | 86.50 | 64.40 | 75.30 | 69.90 | 5.40 | 72.46 | 2.04 |
| S31 | 80.40 | 64.50 | 71.50 | 70.00 | 1.50 | 70.80 | 0.51 |
| S32 | 83.40 | 60.80 | 71.70 | 66.40 | 5.30 | 69.38 | 2.14 |
| S33 | 79.60 | 62.80 | 72.80 | 68.00 | 4.80 | 69.58 | 1.81 |
| S34 | 73.00 | 46.20 | 59.60 | 52.10 | 7.50 | 56.18 | 3.22 |
| S35 | 81.20 | 64.80 | 74.40 | 72.30 | 2.10 | 73.28 | 0.71 |
| S36 | 74.70 | 60.70 | 69.00 | 65.60 | 3.40 | 67.18 | 1.31 |
| S37 | 83.20 | 46.80 | 67.40 | 56.70 | 10.70 | 61.50 | 4.42 |
| S38 | 68.40 | 41.40 | 61.50 | 47.20 | 14.30 | 56.96 | 5.51 |
| S39 | 86.20 | 62.00 | 78.40 | 76.50 | 77.36 | 77.36 | 0.77 |

***The level of sound pollution of stations (morning/evening)***

The measured sound levels in the morning and afternoon at the monitored stations are presented in Table 3. Based on the information presented in Table 3, the average sound level measured in the monitored stations in the morning and evening did not differ significantly, $P_{value}<0.05$, the evenings were slightly higher than the mornings. In the morning, the highest and lowest measured sound values belonged to stations S10 and S20. The measured sound level at stations S10 and S20 was equal to 79.3 and 39.7 dB, respectively. Also, in the evening, the highest and lowest measured sound values belonged to stations S1 and S20. The amount of measured sound level at stations S1 and S20 was equal to 80.9 and 39.7 dB, respectively. Station S20, a completely apartment area, is a completely residential area and this area is located outside the city limits of Khorramabad and there is no industry around it. Also, since the area is entirely residential, there is no street traffic in it, which is confirmed by the measured sound level. Therefore, it was expected which it would have a low sound level, so that the measured sound level in two times, morning and afternoon, was almost the same. The continuous increase in traffic noise in urban areas causes an increase in special problems directly and indirectly affecting daily life, and the high increase in the number of cars and their high speed causes the spread of problems in the areas around the highways [22]. Stations S1 and S10 are both high-traffic and crowded areas of the city, so they are a residential commercial area with high daily traffic. Proximity to the main square, being surrounded by two streets (Alavi and Shariati streets), adjacent to a busy street, the presence of the taxi and city bus station, and the street being surrounded by tall commercial, office, and even residential buildings have finally is led to the highest sound level. Kiani Sadr et al results showed that the change of seasons has no effect on the amount of noise produced in Khorramabad and the daily changes of the average noise in the two seasons of spring and summer are very low and negligible [23]. The results of noise pollution assessment in Omidiye city (Khuzestan province, Iran) showed that the sound level intensity in all three time periods (7-9 am), (12-14 noon) and (19-21 night) and in each three commercial, commercial-residential, and residential areas were above the standard; So that the average sound pressure level in these areas was 72.86, 67.36, and 61.71 dB, respectively [24]. In Iran, according to the official national program, the weekends are Thursday and Friday, where Thursday is half-closed and Friday is completely closed. In Fig. 2, the information of the sound level recorded in some of the monitored stations at the end of the week is shown. Based on the information in Fig. 1 in different stations, in general, the recorded sound level on Thursday was higher than on Friday (holiday). Also, based on statistical tests, this difference was significant. According to the results of this research, it can be concluded that traffic has a direct effect on the amount of noise pollution. The results showed that there is a significant relationship between urban traffic indicators and the amount of noise pollution. Therefore, it was found that urban traffic is also one of the indicators influencing the amount of urban noise pollution.

Table 3. Sound values measured in the morning and afternoon

| | | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | S14 | S15 | S16 | S17 | S18 | S19 | S20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Morninig | 7-7.5 | 73.5 | 74.2 | 73.7 | 64.7 | 65.7 | 69.2 | 69.2 | 69.7 | 72.2 | 74.3 | 72.3 | 73.9 | 72.3 | 75.8 | 72.0 | 71.9 | 75.6 | 51.7 | 45.6 | 41.6 |
| | 8-8.5 | 73.2 | 77.5 | 70.0 | 67.6 | 73.3 | 69.7 | 69.8 | 69.3 | 67.2 | 79.3 | 72.8 | 74.3 | 72.5 | 73.0 | 70.6 | 72.6 | 72.1 | 56.1 | 49.8 | 39.7 |
| | 9.5-10 | 79.5 | 69.1 | 70.9 | 65.3 | 76.4 | 72.1 | 68.6 | 69.7 | 66.3 | 76.2 | 71.1 | 73.7 | 72.7 | 75.1 | 69.2 | 73.2 | 71.0 | 41.5 | 63.3 | 48.1 |
| Evening | 17-17.5 | 74.8 | 73.6 | 72.0 | 71.7 | 64.2 | 71.0 | 71.5 | 72.3 | 70.9 | 74.5 | 73.9 | 74.1 | 74.8 | 74.9 | 70.0 | 71.9 | 71.0 | 41.5 | 58.3 | 48.1 |
| | 18-18.5 | 73.5 | 72.9 | 72.8 | 62.5 | 73.7 | 71.7 | 69.3 | 75.8 | 76.7 | 75.2 | 71.3 | 73.0 | 72.6 | 74.2 | 68.5 | 68.8 | 70.2 | 50.1 | 39.7 | 39.7 |
| | 19.5-20 | 80.9 | 69.6 | 73.1 | 67.4 | 69.8 | 70.0 | 69.2 | 68.0 | 72.4 | 76.1 | 73.8 | 75.3 | 74.0 | 74.7 | 70.9 | 74.6 | 76.6 | 49.0 | 43.6 | 44.2 |
| | | S21 | S22 | S23 | S24 | S25 | S26 | S27 | S28 | S29 | S30 | S31 | S32 | S33 | S34 | S35 | S36 | S37 | S38 | S39 | |
| Morninig | 7-7.5 | 70.3 | 70.0 | 72.7 | 68.7 | 73.9 | 72.4 | 69.8 | 61.5 | 51.1 | 71.3 | 70.5 | 71.7 | 69.4 | 55.2 | 72.3 | 65.9 | 56.7 | 61.5 | 77.3 | |
| | 8-8.5 | 71.0 | 69.3 | 70.1 | 68.4 | 74.3 | 69.4 | 71.5 | 62.6 | 55.0 | 71.0 | 71.5 | 69.0 | 68.0 | 52.1 | 73.0 | 65.6 | 60.7 | 47.2 | 76.5 | |
| | 9.5-10 | 71.1 | 65.5 | 69.7 | 69.1 | 73.7 | 68.5 | 73.2 | 63.8 | 51.8 | 69.9 | 71.1 | 71.1 | 68.3 | 53.0 | 73.0 | 68.2 | 59.2 | 61.5 | 76.7 | |
| Evening | 17-17.5 | 68.5 | 69.0 | 73.2 | 69.6 | 74.1 | 71.0 | 67.7 | 69.9 | 52.1 | 73.6 | 70.0 | 70.7 | 70.5 | 59.6 | 73.7 | 67.5 | 67.4 | 58.8 | 78.2 | |
| | 18-18.5 | 70.0 | 68.3 | 71.4 | 67.5 | 73.0 | 72.4 | 70.9 | 61.3 | 51.4 | 75.3 | 70.9 | 66.4 | 72.8 | 59.2 | 73.3 | 69.0 | 66.5 | 58.8 | 78.4 | |
| | 19.5-20 | 69.1 | 72.3 | 72.1 | 69.2 | 75.3 | 76.3 | 69.5 | 66.9 | 54.1 | 73.7 | 70.8 | 67.4 | 68.5 | 58.0 | 74.4 | 66.9 | 58.5 | 54.0 | 77.1 | |

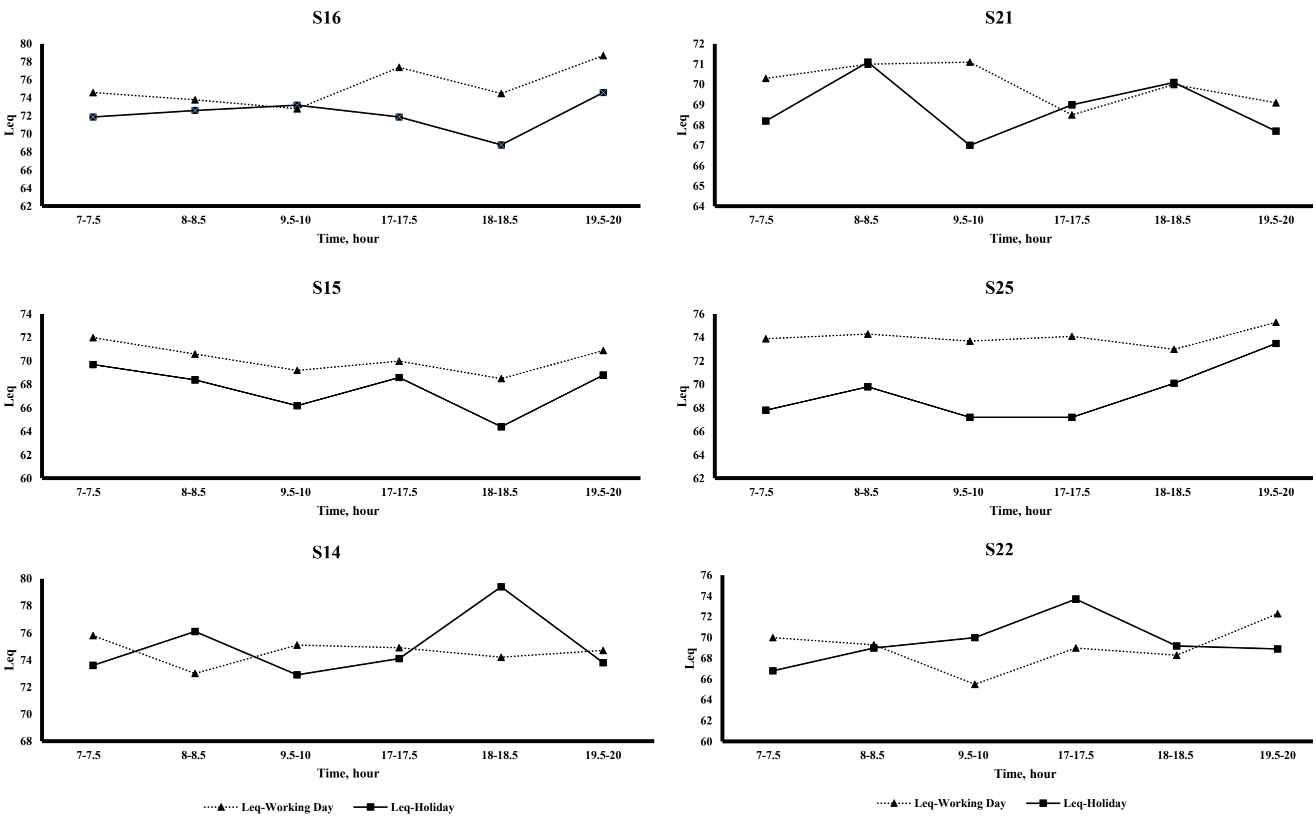


Fig. 2. The information of the sound value recorded in some of the monitored stations at the end of the week

### *The level of sound pollution of stations based on the type of study area*

The measured sound level in different stations was, also, analyzed based on the type of area (residential, residential-commercial, and commercial). The number of residential, commercial-residential and commercial stations was 18, 12, and 9, respectively. The amount of measured sound level according to the type of the studied area is shown in Table 1. Based on the information in Table 4, the highest and lowest sound recorded belonged to stations S39 and S20, respectively. The area type of stations S20 and S39 was commercial and residential, respectively. As mentioned before, station S20 is located in a completely residential area, which is almost outside the city, or close to the city. Also, station S39 is located in the south of the city, due to the high density of population in this area and the high traffic of vehicles, a high level of noise pollution has been recorded daily. If you compare the standard sound level with the sound measured level in different areas, it can be found that the sound value is higher than the standard in most areas. Based on the recorded information, only in two stations S18 and S20 the recorded sound level was lower than the standard value. Stations S18 and S20 are both residential. The highest recorded sound level in residential, residential-commercial and commercial stations was 75, 74, and 77 dB, respectively. In Sanandaj (Kurdistan Province, Iran), Katorani reported that the studied commercial (73.7 dB) and commercial residential (71.32 dB) areas were among the areas with the highest amount of noise pollution [1]. Considering that the limit of noise pollution for residential areas is 55 dB, the level of noise pollution for most of the investigated areas in Sanandaj, including residential and commercial, was more than the limit. Also, the equivalent level of sound pressure was higher than the standard level, which is due to the growing trend of modernization of the city and the increase in population, and as a result, the increase in city traffic, which is one of the main factors in the production of noise pollution, in the near future of the city level. At all hours of the day and night, in terms of noise pollution, it exceeds the standard, which puts the health of the society at risk.

Table 4. Compare to standards for residential and commercial regions of the city

| Station | Zone | Sound level Standsrd (db) | Mean of Measured Sound level (db) |
|---|---|---|---|
| S1 | Residential | 55 | 75.90 |
| S2 | Residential | 55 | 72.81 |
| S3 | Residential-Commercial | 60 | 72.08 |
| S4 | Residential-Commercial | 60 | 66.53 |
| S5 | Residential | 55 | 70.51 |
| S6 | Residential-Commercial | 60 | 70.61 |
| S7 | Residential | 55 | 69.60 |
| S8 | Commercial | 65 | 70.80 |
| S9 | Residential | 55 | 70.95 |
| S10 | Commercial | 65 | 75.93 |
| S11 | Residential | 55 | 72.53 |
| S12 | Residential-Commercial | 60 | 74.05 |
| S13 | Commercial | 65 | 73.15 |
| S14 | Commercial | 65 | 74.61 |
| S15 | Commercial | 65 | 70.20 |
| S16 | Residential-Commercial | 60 | 72.16 |
| S17 | Residential | 55 | 72.75 |
| S18 | Residential | 55 | 48.31 |
| S19 | Commercial | 65 | 50.05 |
| S20 | Residential | 55 | 43.56 |
| S21 | Residential | 55 | 70.00 |
| S22 | Residential-Commercial | 60 | 69.06 |
| S23 | Residential-Commercial | 60 | 71.53 |
| S24 | Residential | 55 | 68.75 |
| S25 | Residential-Commercial | 60 | 74.05 |
| S26 | Commercial | 65 | 71.66 |
| S27 | Residential-Commercial | 60 | 70.43 |
| S28 | Residential | 55 | 64.33 |
| S29 | Residential-Commercial | 60 | 52.58 |
| S30 | Residential | 55 | 72.46 |
| S31 | Residential | 55 | 70.80 |
| S32 | Commercial | 65 | 69.38 |
| S33 | Residential-Commercial | 60 | 69.58 |
| S34 | Residential | 55 | 56.18 |
| S35 | Residential | 55 | 73.28 |
| S36 | Residential-Commercial | 60 | 67.18 |
| S37 | Residential | 55 | 61.50 |
| S38 | Residential | 55 | 56.96 |
| S39 | Commercial | 65 | 77.36 |

With a more detailed examination of the data in Karami et al. study, they were found that the level of sound intensity was different in three time periods, so it can be concluded that the two variables of place and time are effective in the intensity of noise pollution [25]. To control and manage the areas where the noise exceeds the permissible limit, it is necessary to prepare sound maps [19]. In order to model noise pollution and show critical points, various researchers have measured the level of sound intensity in different parts of the city and have drawn a map of environmental noise. So far, many studies have been done by domestic and foreign researchers in connection with the evaluation and modeling of noise pollution [26, 27]. Most of the studies show that in most countries, the average values of the sound equivalent level are far beyond the ambient sound standards. Noise pollution zoning map presents in Fig. 3. One of the suitable methods for displaying data in various topics, especially environmental, noise pollution, is to use temperature software and prepare a map for better advice [28]. According to Fig. 3, the most noise pollution in the central part of the city was towards the southwest, the reasons for which can be the crowdedness of the city center and the fact that most commercial and service areas are located in this part of the city and it has the most traffic of public vehicles. Based on the information shown in Fig. 3, most medical centers are located in areas with very high noise pollution, and educational centers, which are mostly located in the central part of the city, have a sound level higher than the standard. Karimi et al by evaluating the 14th district of Tehran and comparing the average sound equivalent level in all stations with the Iranian sound standard, Ahmadi et al found that the sound intensity was higher than the standard level in all stations. Based on the results of the measurements, 26 of the total 46 stations have a sound equivalent level above 65 dB [25]. Based on the information shown in Fig. 3, as it is clear from the map, the center of pollution is specific to the road network, highway and main roads, and with distance that pollution is reduced,

The zoning results of Sanandaj which showed that the central parts of the city have a high level of pollution. In this study, the pollution of the investigated areas was reported due to the presence of government organizations in the city center [1]. In 2009, in Khorramabad city, comparing the results with this study, it can be seen that the amount of noise pollution in this city has increased during the last 10 years, from 2009 to 2019 [23]. The results of the evaluation of noise pollution in different areas of Messina, Italy, showed that in all evaluated areas, the sound intensity equivalent level exceeded the standard limits and this value was very high for areas where human activities are very high [29]. According to the results of the Varanasi city study, 85% of people feel anxious due to traffic noise, and 90% of people considered traffic noise pollution as the main cause of their headaches, blood pressure, confusion and fatigue. In this research, it was found that traffic noise hinders daily activities such as rest, study, correspondence and communication [30]. The noise level intensity in Khorramabad city is higher than the standard level, so that maybe in the not too distant future, noise pollution in this city will be raised as a serious problem; therefore, the investigation of its causes should be considered. So, it is recommended to adopt appropriate strategies to prevent threats to people's health, so that people's anxiety level decreases and health increases. The results of Pathak et al. study showed that areas with green spaces and parks play a significant role in reducing noise pollution, that in the areas with vegetation and green space, the sound equivalent level was calculated to be lower than the standard limit [30, 31].

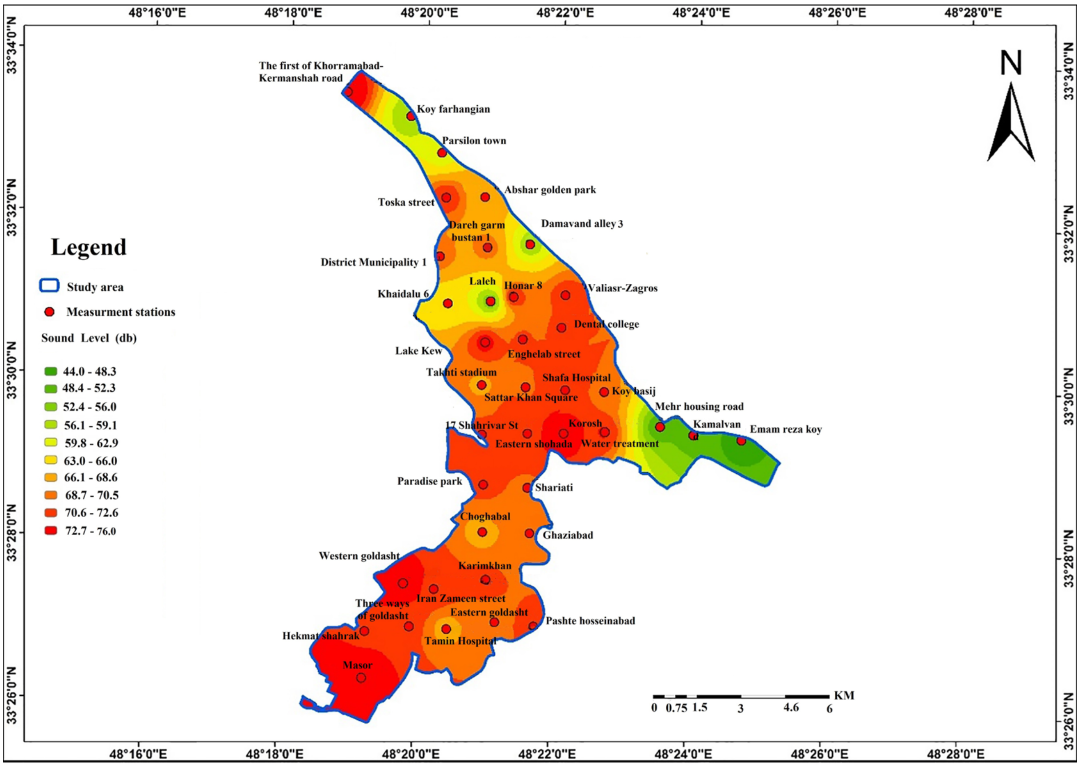


Fig. 3. Adsorbing sound level zones in the city

Noise measurement is the precursors to determine the priorities in determining and recognizing the affected areas and judgments about the results and control methods [32]. By having basic information and data about people who are exposed to noise, it is possible to predict the conditions of noise pollution and evaluate its effect. The standard based on which they determine how to manage and deal with noise pollution is very different in different countries [33]. Unfortunately, our country has performed very poorly in this regard, and in some aspects, it basically lacks criteria or useful basic data. Khorramabad, like other cities, is suffering from traffic problems due to the excessive increase in vehicles and the lack of effective mechanisms to impose restrictions on the use of private vehicles. Today, this problem has caused people to rush to the highways and bypasses of the city to escape from the traffic in the city. The problem of traffic in this city is one of the challenges of this city. The main cause of the traffic problem in this city is the lack of proper infrastructure in the city [34]. To reduce noise pollution in this city, measures such as creating green spaces around the streets as sound absorbers, concentrating commercial areas outside residential areas, preventing urban development and construction operations during certain hours of the day and night, public education through courses training and installation of signs, cultural growth in traffic management, reduction of motorized vehicles, especially motorcycles, and more use of non-motorized vehicles such as bicycles, banning the movement of trucks and trolleys in the city by improving traffic engineering can be recommended [26, 33, 35].

## Conclusion

Based on the results of the study, there was a significant difference between stations in the morning and evening. Therefore, only in less than 10% of the monitored stations, it was within the acceptable range. Also, there is a significant difference between the maximum sound level and the minimum sound level in the morning and evening shifts. Considering that the sampling time was autumn and in the early morning, the weather is colder, people prefer to stay at home and have less traffic. Other reasons include the opening hours of commercial areas, which are quieter in the morning than in the evening. The difference in the average sound equivalent level in the morning and evening was significant, which can be justified considering that these areas were commercial-residential and the amount of traffic in the evening is more than during the day. Therefore, among the methods of dealing with noise pollution in cities, we can find suitable location of urban uses in comprehensive and detailed plans, producing standard and quiet vehicles, imposing restrictions on the traffic of cars and motorcycles, creating speed limits, improving traffic culture and expanding Public transportation pointed out. Also, the construction of sound walls around the roads and the use of sound absorbing materials in residential and commercial units or green spaces around residential houses or roads will help a lot in reducing city pollution. Appropriate number of noise pollution measurement stations and preparation of sound zoning maps for different areas and uses of the whole city are necessary for any city-wide planning.

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## Competing interests

The author declares that they have no competing interests.

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## Ethical considerations

"Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc) have been completely ob-served by the authors."

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