



## Noise pollution and its spatial distribution in urban environments (case study: Yazd, Iran)

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### Original Article

#### Abstract

This study focuses on identifying source and frequency of noise pollution in Yazd, Iran. For data collection, we used two approaches: First we selected 55 monitoring stations for 122 km grid network; the distance between two stations was 2 km. Then, at the same time, we measured the sound pressure level (SPL) at main roads; the distance between two monitoring stations in this case was 1 km. After collecting data required, noise map of each collection and composite map were provided using ArcGIS software in geographic information systems environment. It was founded that the maximum noise pollution was created by vehicles in Yazd. The map based on 2 km network showed that 99% of residential areas were exposed to noise pollution. Composite map showed that 56% of Yazd lands were exposed to noise pollution. In addition, other activity zones such as university, administrative and commercial were in critical pollution conditions. Moreover, due to the surrounding sources such as airport and industries, the SPL in the western and eastern parts of the city was too much, so that it is a limiting factor resulted in the city development most properly toward those parts. We propose a project to define the impact of industrial noise pollution on residential land in the eastern and western parts of the city. Nevertheless, due to the high pollution levels in the city center and because of existence of uses such as bazaar in historic area of the town, residential areas, some small shops and major hospitals of the city, the pollution and exposure must be reduced.

**KEYWORDS:** Noise Pollution, Cities, Environmental Pollution, Geographical Information Systems, Noise, Urban Development, Iran

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#### Introduction

No one would be able to escape from the effects of manmade life. Urbanization and industrialization along with growth of population have brought about environmental issues in many metropolitans and cities throughout the world. Noise pollution is one of the most important issues in big cities causing disturbance in urban areas and nowadays is considered as a serious threat to the quality of

modern life.<sup>1,2</sup> Noise pollution sources in urban areas mainly include construction activities, workshops, industrial and commercial units, and traffic. In this regard, impact of vehicles and cars on human health is obvious so that it influences the everyday life of inhabitants, work, and sleep; hence, study and finding a suitable approach to reduce noise pollution is demanded in urban areas.<sup>3-6</sup> Noise pollution in urban areas has been globally recognized as a major detriment to the quality of life. The adverse effects of noise include various impacts on people's physical well-being<sup>7</sup> and the disturbance of daily activities,<sup>8</sup> which includes: (a) Physical effects

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such as hearing defects; (b) physiological effects such as increased blood pressure, irregularity of heart rhythms and ulcers; (c) psychological effects such as sleep disorders, irritability, and stress; and (d) effects on work performance such as reduction of productivity, communication gap, and hearing impairment.<sup>9</sup>

In 2002, the European Union (EU) passed directive for the assessment and management of environmental noise stipulated by July, 2008. According to this directive, all EU members must draw up noise map for the main areas of population aggregation and primary road systems for public reference. England then published the London noise map in 2004, which is the first noise map produced by a national government, as a reference for London citizens to avoid noise nuisances.<sup>10</sup> Thus, with regard to the sensitivity of the noise and its adverse effects, sound mapping is essential to the public as a tool to show the areas with intensive pollution.<sup>11</sup>

Therefore, the main aim of the present research is to draw Yazd, Iran, sound map using data obtained from 177 points along the main streets and the motor vehicles, and network points between different parts of the city including residential, industrial, and commercial activities. The division of land was according to the specified zones of Iran Environmental Protection Agency (EPA) approved in 2009, which determines the amount of allowed pollution for a five given zones and critical areas.

## Materials and Methods

This study was conducted in summer 2012 by measuring sound pressure level (SPL) at 177 points. The methodology of this research, which was a descriptive case study, is divided into two parts.

According to the type of streets and the density of city, the sound data were collected in two ways in order to determine the SPL in Yazd city. First, we measured the SPL using a sound pressure meter (1353H, TES, Taiwan) at the main streets over a distance of 1 km with respect to the

street distances from each other. The number of monitoring stations (points) determined was 122. The distance between these points was determined mainly based on the criteria such as typology and type of road network in the Yazd city, which was linear. Moreover, we considered the activity nodes and their density along the movement axes of Yazd, which were a variety of commercial and workshop uses. Then, the sound level was recorded as a network with a distance of 2 km; the aim of this monitoring was to gain not only the sound level on the roads but also to obtain the amount of sound resulted from different activities within the city. The distance between these monitoring stations (55 points) was determined based on the Yazd city dimension, urban land use zones in different areas of the city, and accessibility hierarchy. After determining monitoring stations, SPL was recorded at crowded hours (8:00-9:00 AM). The reading was repeated twice. Simultaneously, data related to noise were collected during the same time period.

After data collection, for determining the sound intensity in different parts of the city, data processing was carried out using the ArcGIS software (version 10, Esri, Redlands, CA, USA). For creating the sound maps, first position map of the red and blue dots were prepared using the "editor" tool. Then, data interpolation and sound intensity at each point on the surrounding points were investigated using "spatial analyst" tool, such as interpolation and existing extension of these tools, which include under kiriging and natural neighbor. In the next stage, map of different land use zones was prepared, areas exposed to noise pollution were determined, and areas at the risk of noise pollution were clearly defined.

With increasing vehicles traffic, urban activities in the cities, and disturbing tranquility of living, it has been recognized necessary to create sound maps in order to determine the sound intensity level of noise pollution in different urban areas. In recent years, mass vehicle production, increasing car ownership,

and travel density have made metropolitan and other cities be affected by sound in Iran. Yazd city, located in the center of Iran (desert region) has experienced expansion and population growth in recent years due to various mineral resources and locating on the motor highway including large industries (Figure 1). Today, the legal area of Yazd is about 9,976 ha, out of which 21.4% equivalent to 2,138 ha is residential lands, 18.8% (1,873 ha) road network, 11.9% (1,191 ha) agriculture lands and gardens, 25.7% (2,564 ha) barren and desolate lands, and the remaining land is allocated to other land uses. Table 1 represents the land use categorization and

definition of each zone. Building density in Yazd is averagely 73%.<sup>12</sup> The city has a population of about 550,904 people.

## Results and Discussion

According to the Iran Environmental Protection Department classification, Yazd land uses were zoned and the noisy parts of the city were determined. Then Yazd city noise maps were prepared by measuring the SPL. For this purpose, first we measured the noise frequency production in different parts of the city. By preparing the noise maps based on the data points on the road and raster grid and

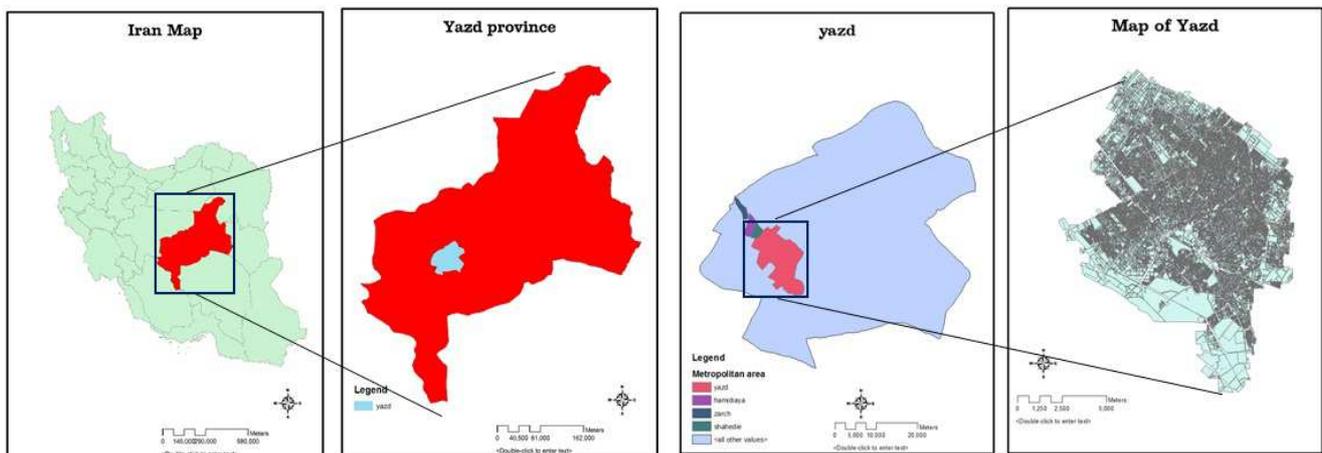
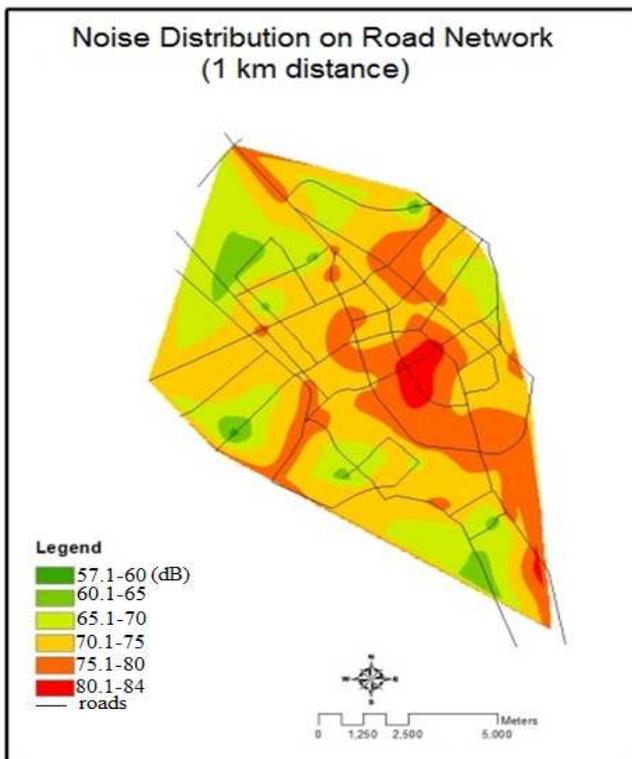


Figure 1. Location of Yazd city

Table 1. Categorizing city land use zones and their definition

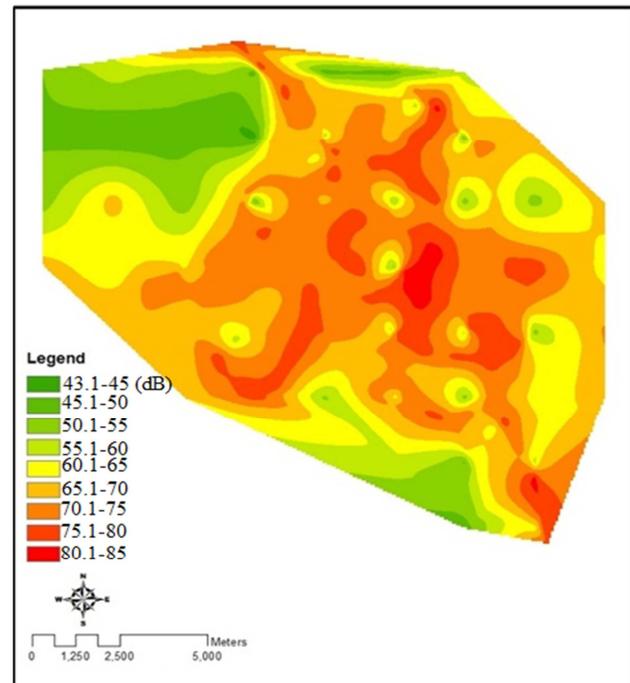
Zone	Definition
Residential	A zone, where more than 50% of the land use is pure residential and the rest (in addition to road network) is consisted of unobtrusive residential-related services
Commercial	A zone, where more than 50% of land uses are predominantly related to offices, recreational, cultural activities, etc.,
Commercial-residential	A zone, where ground floors are commercial and upper stories are usually predicted to be residential; however, residential uses are usually more than commercial ones
Residential-industrial	A zone, where some non-intrusive and non-polluting industries (for example, workshops) are located besides residential areas. Here, the major land use is residential
Industrial	A zone with industrial land use located far away from the residential areas and out of city based on the environmental considerations
Administrative	A zone, where more than of 50% of land uses are administrative
University	A zone, where university has the highest performance
Airport	A zone, where includes airport and its surroundings
Agricultural	A zone, where has a predominantly agricultural uses and is within the residential uses limits
Commercial-industrial	A zone, where more than 50% of the land uses include small industries and commercial uses

comparison with Iran National Sound Standard at Ambient Air (INSSAA),<sup>13</sup> it can be said that the most of the noise pollution is due to the motor vehicles in the city of Yazd. According to the map shown in figure 2, the highest SPL is around the streets while they would influence their adjacent lands. In this map with red dots, the lowest SPL is 57 and its highest is 84 dB, which demonstrates that all the noise pollution is around the streets in residential areas. Moreover, it was found that the most of the noise pollution generated by various activities is in the eastern and western parts of the city causing inconvenience to the industrial-residential and commercial-industrial areas.



**Figure 2.** Yazd city noise map of road network

Finally, to obtain a general sound map of Yazd, we combined both types of data (grid and roads network) in order to obtain the effects of pollution. Comparison of this map (Figure 3) with the EPA standards for five urban zones revealed considerable facts.



**Figure 3.** Noise map of Yazd city

Considering the integrated map and noise pollution permitted limit standards (INSSAA, Table 2) in these zones, we found that Yazd is a city, where:

- 99% of the fully residential zones are in the upper permissible level of noise pollution
- 97% of the residential-commercial areas are in the high level of noise pollution
- 100% of the commercial zones are suffering from noise pollution, according to the red and blue sound map and the location of this zone, all the noise pollution could be attributed to the motor vehicles
- 4% of the residential-industrial zones are exposed to noise pollution sprawled around the suburban
- 75% of the commercial-industrial areas are exposed to noise pollution
- According to standards, the industrial area has no noise pollution
- Due to the nearness of the airport to the Azadshahr town, Iran, the sound measurement importance in airport zone has become crucial. 25% of this area is affected by noise pollution

- Administrative zone is also an important zone, which must be monitored because of its vast area. 2% of the area is at risk of noise pollution
- The entire university zone, which is a residential area, is exposed to noise pollution
  - 58% of the agricultural zone is also affected by noise pollution, and
  - Finally, 56% of the total areas of the city are exposed to noise pollution.

**Table 2. Iran National Sound Standard at Ambient Air (INSSAA)**

Zone	Leq (30), dB (A) from 7 am to 10 pm	Leq (30), dB (A) from 10 pm to 7 am
Residential	55	45
Residential-commercial	60	50
Commercial	65	55
Residential-industrial	70	60
Industrial	75	65

Leq: Sound equivalent level

Many research works have been carried out for identification and analysis of sound sources in order to reduce its impact. Tsai et al. analyzed the spatial characteristics of urban environmental noise using noise maps produced at 345 noise monitoring stations in Tainan, Taiwan. Noise data were collected at varying intervals: Morning, afternoon, and evening in both summer and winter in various areas of commercial, residential, and cultural zones and they compared it with standards of sound control. Their findings showed that about 90% of Taiwan's population was exposed to unacceptable noise generated by urban development.<sup>10</sup> In another study, it was referred to negative impact of noise on the quality of life that is one of the serious concerns in Vietnam. Cameras were installed to measure quantitative volumes of traffic and compared it with Japan data. It was concluded that the noise of means of transportation is very relevant to car horns,

where noise levels decreased with the absence of horn sounds.<sup>14</sup> In another research work conducted in Delhi and India, some suggestions such as land use and transportation planning were given for mitigating and managing the noise pollution problem in the sustainable urban development perspectives.<sup>7</sup> All of the above restudies had a view of improving the environment, while our study aimed at determining the amount of noise pollution generated by different activities. This is very useful in the preparation of urban development plans and prevents unnecessary costs in future development. Moreover, through field observation, this survey indicated that the maximum amount of noise pollution in Yazd city is due to the private vehicles, especially in the downtown, where the existence of bazaar and markets has brought maximum visits in this area. In addition, it was found that the historic fabric of downtown is exposed to noise pollution indicating the importance of conducting this study in future plans in order to attract tourists and preserve monuments.

Figure 4 shows the area of each zone classified. Moreover, table 3 presents the SPL range and related area of each zone. After investigating and preparing Yazd sound map and overlaying this map on the land use map, it was revealed that noise pollution is at a critical level in residential areas in Yazd city (Figure 5). Other lands except industrial and residential-industrial zones had high level of noise pollution. Therefore, we conclude that most of the noise pollution is caused by motor vehicles in the Yazd city, which includes a large area (about 56%). In addition, administrative zone, university and airport were evaluated because these areas are sensitive to noise pollution like other areas. The noise level at airport was remarkable due to exposure in metropolitan and residential settlements of Azadshahr (a district name). Academic and administrative areas are not an exception and were influenced by noise pollution.

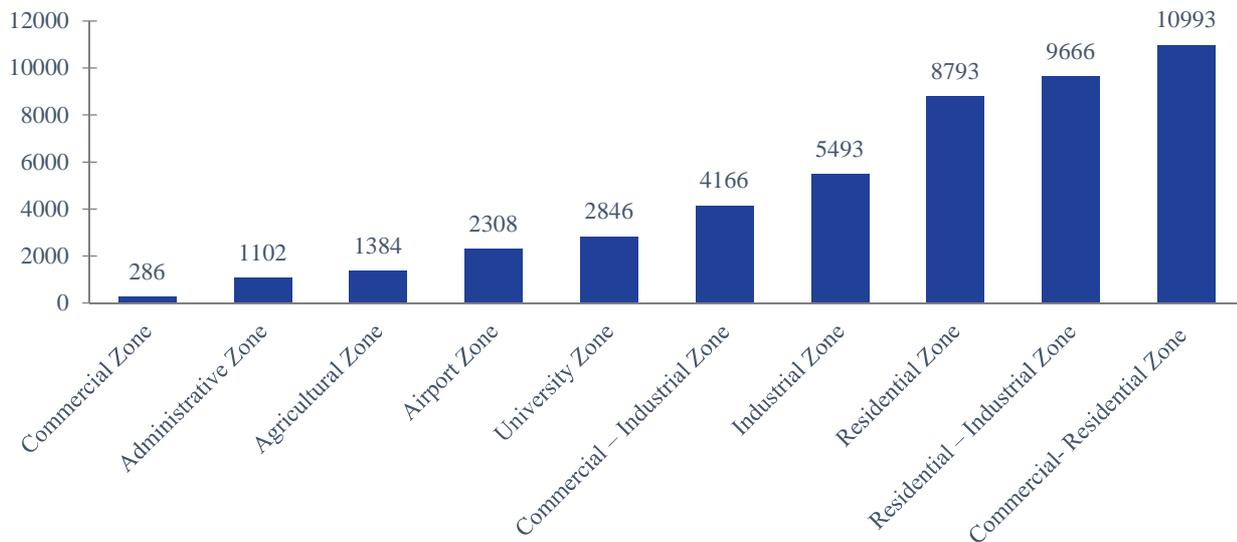


Figure 4. Zone area based on different land uses

Table 3. Sound pressure level (SPL) (dB) range of each zone area (ha)

SPL range (dB)	Agriculture	Commercial	Commercial residential	Residential	Industrial	Industrial commercial	Industrial residential	University	Official	Airport
40.0-45	0	0	0	0	0	33	0	0	0	0
45.1-50	0	0	1	2	80	367	1068	0	0	937
50.1-55	0	0	30	54	886	509	1780	6	0	923
55.1-60	4	0	279	443	613	149	1507	667	1	276
60.1-65	244	0	1499	920	788	223	3014	1103	23	121
65.1-70	340	8	3669	1845	2311	1099	1912	667	291	51
70.1-75	456	154	4489	3600	806	1334	327	381	575	1
75.1-80	323	114	1014	1590	9	675	58	22	212	0
80.1-85	17	10	12	339	0	0	0	0	0	0
> INSSAA*	796	286	10683	8737	9	3108	385	2840	1078	449
≤ INSSAA**	588	0	310	56	5484	1058	9281	6	24	1860

\* Total zone area exceeding INSSAA; \*\* Total zone area not exceeding INSSAA; SPL: Sound pressure level; INSSAA: Iran National Sound Standard at Ambient Air;

## Conclusion

We found that 56% of the land in Yazd city is suffering from noise pollution and 100% of residential area is polluted. Moreover, noise pollution has pervaded the entire region in the central area (i.e., downtown) including commercial areas. Administrative zone, the university and the airport had noise pollution, which of course these zones are not in EPA standards. Pollution is, now, very sensitive and crucial in Yazd according to the results achieved. Noise pollution studies must be taken into

account in the urban plan processes such as Yazd master plan and strategic development plan. With regard to the results of the industries and factories noise impact in the eastern and western parts of the city, it is essential to make serious steps toward revising the residential construction (which are now growing in all four directions) and preventing the annoying sound. Therefore, we propose a project to define the impact of industrial noise pollution on residential land in the east and west part of the city. Nevertheless, due to the high pollution levels in the city center and because of existence of uses such as

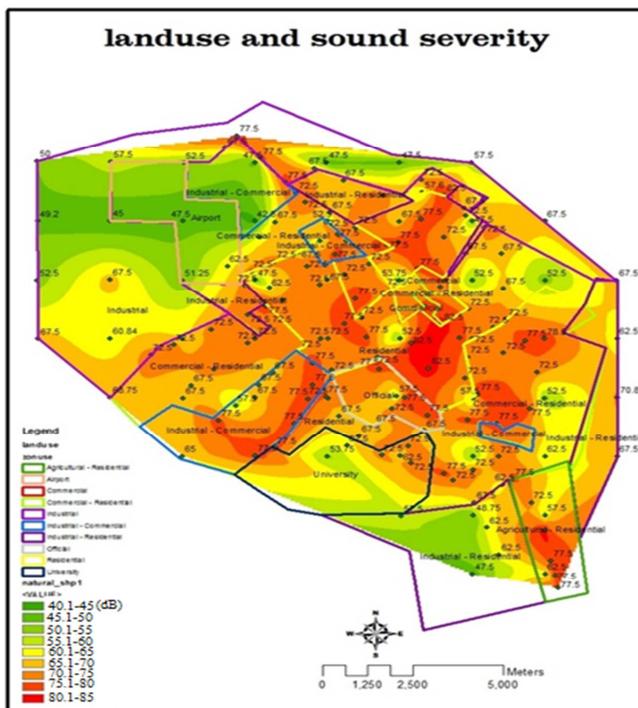


Figure 5. Comparison of the landuse and the sound map of Yazd city

bazaar in historic area of the town, residential areas, some small shops and major hospitals of the city, the pollution and exposure must be reduced. There are some important uses in this area for the local region, which makes it to be considered as the most important part of economy in the city. This research proposed sound barrier to prevent the noise in short-term, and also refers to planning in order to permanent adjustment of the contamination causes in long-term. Thus, factors that increase vehicle traffic should be identified and then modified, changed and improved in this area. About academic, administrative and airport areas covering a considerable area of city due to similarities with other cities, it is recommended that EPA reconsider its standards.

### Conflict of Interests

Authors have no conflict of interests.

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