Acoustic loading in modern city as negative factor of sustainable development

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Abstract. At the present time, acoustic contamination is one of the largest ecological problems, which people face with in a big city. It is impossible to eliminate road traffic noise, thus regulation and limitation of environmental noise pollution are important and obligatory actions. Noise can negatively affect human health, vegetal and animal world. Its harm depends on intensity, frequency and duration. Under the current conditions noise control is technically complicated, complex and economically wildly expensive. The study of noise level was performed in the territories, boarded on main traffic arteries of Kharkiv without rail transport and with rail transport. The studies showed that the roads with rail transport are 7-14 dB louder than the roads without it. The average noise level on highways of the city ranged 80-94 dB, besides on some of the highways the average noise level did not reach the statutory level at 100 m from traffic roads. Such noise load level in the urban environment requires implementation of solutions, directed at its reduction. The impact of the noise barrier and green planting on noise emission is studied.

1. Introduction

In recent year conception of steady development gets considerable distribution in the entire countries the world as one of leading global problems humanity that is examined in many aspects and foreshortening. Introduction of strategy sustainable development conditioned by the necessity of stabilizing the technogenic loading on a natural environment, and also decision of complex ecological problems in the conditions of socio-economic increase. Priority direction of sustainable development is optimization vital functions of humanity in the conditions of safe natural environment and harmonious relations both into society and between separate associations.

It is changed by a man, degraded an artificial urban environments have a complex effect on a health of population as a result of air pollution, deficit of sunbeam, water, and also stress factors, that is predefined by the tense rhythm of life, congestion of population, by insufficiency of green plantations and others like that. Some problems have already reached a global nature and need to be addressed urgently to create a “safe” environment for humans and their generations.

Now there is a tendency to expansion the areas of acoustic discomfort on built-up territories. Imperfection of normatively-legal base, absence of economic instruments adjusting of possible sound-levels, is the cause of increasing acoustic pollution of cities. As the result of development of industry, transport and infrastructure in modern person’s life, new kinds of noise appear. With each passing year the noise level in big cities is constantly growing due to expansion in the number of vehicles that move constantly in the entire territory of the city.
Over the past 30 years in all big cities the noise level has increased by 12-15 dB, and subjective loudness has increased by 3-4 times. Furthermore, the noise level is close to the red lines – 80 dB in the modern urban areas with heavy vehicle traffic. Approximately 30% of urban population suffers from noise. This interferes normal sleep, rest, reduces working efficiency, affecting central nervous system, the noise causes changes in heart function, fatigue of a bode as a whole, increases blood pressure, sometimes leads to amblyacusia [1].

By its impact on a human body the noise is more harmful than chemical pollution. The noise slowed down efficiency by 15-20%, significantly raised excess incidence. Excessive street noise causes headaches in 80% of people, memory impairment and neurosis in 52%. The noise causes ageing in 30% of city residents and reduces duration of life by 8-12 years [2, 3]. For this reason, responsible and active fight with environmental noise is an integral part of the problem of human society cooperation.

Major noise sources in the city are [3-8]: means of transport (automobile, rail and air transport); industrial enterprises; railway branches and highways; garages, parking areas, gas stations and service stations; places of mass gathering (stadiums, trade fairs, shopping centers, markets, children’s playgrounds, etc.); transformer plants; noise of industrial enterprises; at home additional noise from household appliances, radio and television equipment, minor home repair works; inhabitants themselves.

The noise regime of the city is related with its planning, which determines the organization of the traffic route and the possibility of zoning the territory with the appropriate placement of individual objects on it. This creates a certain level of noise on the streets, in recreation areas and houses for various purposes.

Different sources of technology-related noise make an important contribution in sound environment of the city, but still the main source in the city is ground automobile and rail transport. It causes 80-90% of the street noise level. When the scales of motor-car motion grow, the zones of acoustic discomfort increase considerably. On many streets of large cities, noise from public transport exceeds the permissible level by 25-35 dBA [9].

Cars make the largest contribution to the overall sound power of transport noise. They are sources of low-frequency noise, which has a high permeability. Increasing the amount of freight and public transport by 13% in traffic flows increases the noise by 1 dB [10]. The noise level at intersections is 3-6 dB higher than in areas with constant traffic [11].

Therefore, the problem of combating traffic noise has an environmental, social and economic significance. The intensity of road traffic noise depends on many factors such as: the condition of roads, road widths and the distance of residential buildings from the axis of the roadway.

All noise sources in size (relatively to geometrical parameters of the source) are divided into 3 types [4, 10, 11]:
- dotted (transformer plant, ventilation unit, automobile, plant, children’s playground, etc.);
- linear (highway transport flow with traffic intensity 5000-6000 vehicles per hour, train that moves, etc.);
- spatial (industrial areas, logistic centers, bus stations, automobile enterprises, transport junctions, etc.).

Depending on distribution of sound energy over time, noise occurs [14]:
- constant – noise, the sound level of which changes over time by no more than 5 dBA, measured by a noise meter,
- intermittent – the sound level changes over time by more than 5 dBA.

In turn, intermittent noise occurs [14]:
- intermittent – intermittent noise, the sound level of which periodically drops sharply to the level of background noise, the duration of the intervals during which the level remains constant, is 1 s or more,
- impulsive – intermittent noise, which consists of one or more sound pulses, the duration of each of them is less than 1 s;
- hesitating – noise, the sound level of which changes continuously over time.
Depending on the geographical distribution of the city, the noise sources are divided into: noise sources of residential and away from residential territories [4]. The following noise sources are found on the residential territory of the city: traffic flows, rail transport; some industrial and communal and storage enterprises; railway branches and motorways; parking areas, garages, gas stations and service stations; dance, concert venues; sports, public utility sites; transformer plants; children’s playgrounds; trading floors. Furthermore, there are noise sources inside buildings.

2. Unresolved issues

By research of the impact of traffic noise on the environment is devoted to the works of the following domestic and foreign scientists [3]: E P Samoilyuk, G L Osipov, O O Kruze, E Y Yudin, B G Prutkova, P I Pospelova, M I Ivanova, MacKenzie Leo Davis, P M Nelson, M Kapusta and others.

Each person has a different reaction to the noise: some people perceive it “calmly”, while it produces strong annoying effect for others. If a person lives long enough in a place with high noise levels, it can cause not only psychological but also physiological changes that are a direct threat to human life. Prolonged exposure to noise causes increased morbidity. Intensive noise reduces a person's attention, increases the number of errors when performing any work.

As under the conditions of strong urban noise constant tension of an acoustic analyzer arises, its permanent action may not only negatively influence on sense of hearing, but also cause such harmful results as: ringing in the ears, headache, quinism, sickliness, irritation, excessive fatigue, rise of blood pressure, even hearing loss.

Furthermore, excessive noise may cause nervous exhaustion, psychic despondency, vegetative neurosis, stomach ulcer, disorders of endocrine, central nervous and cardiovascular systems [2]. In the result so called “noise sickness” appears. It occurs in uprising of headache, sickliness, irritation, which are often followed by temporary loss of hearing.

Most of inhabitants of big cities, who constantly receive noise loads, suffer from noise sickness. Such noise interferes people to work and rest, interferes normal sleep, reduces labor productivity.

The noise affects the human body, not only directly, but also indirectly. Its influence depends on the level and nature, duration of action, as well as on individual characteristics of a person: temperament, state of health, age [3, 9, 12, 13, 15–20].

The greatest hazard of noise is that it is able to be accumulated and each time strongly to affect the nervous system, suppressing it. Some people lose their hearing even after a short noise exposure relatively to increased intensity.

Noises that are particularly unfavorable for the human body are sharp, unstable, unexpected and such that they repeat irregularly. Numerous studies have confirmed the fact that noise refers to general physiological stimuli, which under certain circumstances can affect most organs and systems of the human body.

The action of noise different levels is characterized as follows [6, 9]:

1. Noise up to 50 dBA (usually does not have a harmful effect on a person in the course of his work).

2. Noise of 50-60 dBA (may have a psychological effect, which is manifested in the deterioration of mental activity, weakening of attention, speed of reaction, difficulty working with arrays of information, etc.).

3. Noise 65-90 dBA (possible physiological effects: heart rate increases, blood pressure increases, blood vessels narrow, that worsens the supply of organs blood).

4. Noise of 90 dBA and above (can lead to functional disorders in organs and systems of the human body: deteriorating activity of the stomach and intestines, decreased auditory sensitivity, tinnitus, nausea, headache).

5. Noise of 120 dBA and above (there is a mechanical impact on the hearing organ, which is manifested in the violation of connections between individual parts of the inner ear; even a rupture of the eardrum is possible, there is an impact not only on the hearing organs but also on the whole body, sound waves, penetrating through the skin, cause mechanical vibrations of body tissues, resulting in the destruction of nerve cells, rupture of small vessels, etc.).
In Ukraine, the standard permissible noise level in the environment is 55/45 dBA (day/night) for the residential area, 40 dBA for the recreation area, 65/55 dBA (day/night) for the first line of buildings from the railway track [3, 8].

The objective of the experimental researches was to determine the level of acoustic load in urban areas (for example, Kharkiv) and the protective effectiveness from it by means of the noise barrier.

3. Main part
In the work, the studies were performed to determine the noise levels in Kharkiv in the afternoon in the territories, boarded on highways without rail transport – Sumska street, Pushkinska street, Myronosytska street, Alchevskykh street, Dynamivska street, and to highways with rail transport – Poltavskyi Shlyakh street, Klochkivska street, Moscovskiy avenue. To perform measurements, the noise level meters VShV-003 and FLUS MT-901A were applied. The difference between the values of the noise load performed by various measuring devices was 1-3 dB. At each section, measurements were performed 5 times, the tables show the average results. The streets were chosen taking into account the traffic intensity, type of surface and the distance of the carriageway to the residential construction, taking into account the presence of trees near the highway and the location of the tram tracks.

The results of the performed measurements are presented in table (refer with: Table 1, Table 2).

Table 1. The research results of acoustic load in the noisiest streets of Kharkiv without rail transport

| Place of research | Road material | Traffic intensity, [car/day] | Noise level at a distance from carriageways, [dB] | Distance, [m] |
|-------------------|---------------|-----------------------------|-----------------------------------------------|--------------|
| Sumska street     | paving stone  | 31064                       | 94/94, 86/85                                  | 78/78, 70/71 |
|                   | blocks        |                             |                                               |              |
| Sumska street     | asphalt       | 31041                       | 85/85, 80/80                                  | 76/75, 64/63 |
| Pushkinska street | asphalt       | 23040                       | 84/83, 79/78                                  | 72/70, 61/60 |
| Myronosytska street | asphalt | 7856                        | 80/82, 74/75                                  | 68/69, 50/50 |
| Alchevskykh street | asphalt      | 8624                        | 82/83, 74/75                                  | 64/65, 55/54 |

* in the numerator measurements were performed by means of the sound level meter VShV - 003, in the denominator – by means of the sound level meter FLUS MT-901A

As it is seen from the results of measuring of the acoustic load on streets with heavy traffic density without rail transport (refer with: Table 1), the noise level at 1 m from the carriageways (asphalt coating) depends on the traffic density and ranges from 80 to 94 dB (at the sanitary standards 55 dB at daytime). As it was determined, the noise level measurements in Sumska street, stone block pavement causes increase of the noise level about 10%. Even at 20 m from the roadway, the standard values of noise rates in the examined streets are not achieved. But at 50 m in the streets with less traffic density (Myronosytska and Alchevskykh) the noise is within the standard values. The highest noise level is formed in Sumska street at the sections with carriageways from stone block pavement that has hollow spots.

In the course of the work, the noisiest streets with the rail transport were examined, specifically: Poltavskyi Shlyakh street, Klochkivska street, Moscovskiy avenue (refer with: Table 2). The results showed that the acoustic load level is over the limits even at 50 m from the roadway, and even much less next to the carriageways.

The researches have shown (refer with: Table 1, Table 2) that roads with rail transport are 7-14 dBA louder than roads without it. As it is seen from the results of measuring the acoustic load in places with heavy traffic density, including with rail transport, the noise level at 1 m from the carriageways is 90-94 dB. Moving from the carriageways, the noise is certainly damped (and the acoustic load is reduced), but still it does not reach an environmentally-friendly safe level even at 50 m from the carriageways.
Table 2. The research results of acoustic load in the noisiest streets of Kharkiv with rail transport

| Place of research         | Road material | Distance, [m]     | Noise level at a distance from carriageways, [dB] |
|---------------------------|---------------|------------------|-----------------------------------------------|
| Poltavskyi Shlyakh street | asphalt       | 1                | 92 / 94, 80 / 83 / 75 / 76 / 61 / 63          |
| Klochkivska street        | asphalt       | 10               | 94 / 93, 80 / 80, 70 / 70, 57 / 60            |
| Moscovskiy avenue         | asphalt       | 20               | 94 / 94, 85 / 85, 78 / 78, 70 / 69            |
|                           |               | 50               |                                               |

* in the numerator measurements were performed by means of the sound level meter VShV-003, in the denominator – by means of the sound level meter FLUS MT-901A

Reduction of the acoustic load in these areas of the city needs modernization of the tram depot. Modernization includes the following works: installation of a depreciated floor, false bags with sound absorbers closing the wheels, replacement of tram carts, rubber tram wheels, replacement of double-glazed windows, replacement of door cylinders with silent ones, modernization of electronics.

The determined noise level rates in the territory of Kharkiv are in line with the data of other researchers: average sound levels on highways of big cities – 73-83 dB (maximum – 90-95 dB), in residential buildings along the main roads – 62-77 dB [3].

Generally, the determined excess of permissible noise levels in the streets of Kharkiv is caused by high traffic density in the streets cobbled with pebbles, existence of tram tracks and the movement of tram cars in the general traffic flow. According to the research results, it can be argued that the streets where residential buildings are located in the immediate vicinity of the automobile road with the coating type - paving stone blocks have the highest noise levels, which, as known, interfere the normal life of the residents of these streets and negatively affect their functional status. The determined rates indicate the necessity to improve the environmental safety of residents of these streets through the implementation of special solutions to reduce acoustic load.

It is known that green planting, shaped in the form of special soundproofing strips, can reduce the noise level by 8-10 dBA. Trees, which are planted close to each other and surrounded by dense bushes, significantly reduce the level of man-made noise and improve the urban environment. And particularly the green planting in Kharkiv is the most common method of protection from the noise level.

In the course of the work the noise-proofing properties of green planting along the carriageways of the city and the noise screen in Dynamivska street (refer with: Table 3) were examined. As indicated by the data presented, the green planting in Kharkiv in the noisiest central streets of the city do not have any noise protection properties because the trees on the sidewalks are planted in one or two rows at a 4-6 m from each other, while the tree crowns cannot create enough protective mass dense even at an age when all the tree properties are fully presented (the average height of the trees is 7-8 m, and the crown is at a height of at least 3.5 m); for street planting commonly standard trees are used, that allows freely spread of the sound to residential buildings. But the usage of a noise shield allows reducing noise in the examined area by 10 dB. Therefore, the installation of such screens on large and noisy highways will significantly reduce the acoustic load. According to the foreign experience, the noise screens protect surrounding houses from noise, as well as crowded places (public transport stops, parks). The installation of such constructions is economically feasible in densely populated areas where road location at a distance from residential and office buildings is not possible. Thus, even when passing in the immediate vicinity of a busy highway – it is possible to create a quiet, residential area.

Nowadays in Ukraine there is a significant number of normative-legal acts of ecological, sanitary-hygienic, transport, administrative and other legislation, which regulate issues related to protection of the population from dangerous noise influences. Also, to solve the problem of noise reduction, it is important to predict the noise background of cities.
Protection methods against external urban noise usually have a complex character. In order to reduce the acoustic load level in the city, it is necessary to use several noise protections measures together

- technological (development of more advanced vehicles and industrial plants relating to acoustic);

- constructional and acoustic (increasing of sound-proofing of building envelopes, shielded and architectural and planning solutions for buildings taking into account noise influences, arranging of noise-proof windows in buildings, removing of residential space from the ground floors of buildings and arranging of uninhabited facilities there (commercial, assembly space, offices, food outlets, etc.)

- city planning (development of roadside clear zones, functional noiseproofing zoning of urban areas, usage of green planting, acoustic shielding (natural and artificial relief elements, roadside barrier, retaining and special protective shields-walls)

- administrative and organizational (rational organization of traffic flows, differentiation of transport types as per special lanes (as per speed), their separation at various levels, prohibition of sound car signals, time regulatory actions of loud sources or prohibition of their work, restriction of the movement of trucks and motorcycles in certain city areas and as per time, removing of noisy enterprises outside the residential districts).

An effective preventive measure in the noise control is application of vehicles with minimal noise level. An important action in the noise control is proper planning of residential places, construction of belt highways that unload the city center, and reduction of the number of road intersections in the territory of a residential area. Furthermore, construction projects should provide maximum protection of residential districts from noise by means of development of natural and artificial screens, green planting (trees planted close to each other, surrounded by dense bushes, significantly reduce the industrial noise level and improve the urban environment), transfer of engineering structures under the ground.

4. Conclusion

1. The noise control in the city is one of the most pressing challenge of human habitat protection. It is aimed at reduction of noise level and involves a wide range of various general and special activities.

2. The noise rating in the daytime in 8 streets of Kharkiv, which differed by availability/absence of rail transport, traffic density, road material, availability/absence of green planting, was carried out.

3. It was established that the average noise level in the territories boarded on the city highways without rail transport at 1 m from the roadway ranges from 80 to 94 dB, and on the highways with rail transport – from 90 to 94 dB. The standard values of the noise level (55 dB) were reached only at 50 m from the carriageway and only in streets without rail transport, and with low traffic density (Myronosytka and Alchevskyykh).

4. It was found out that usage of a noise screen reduces the noise level in Dynamivska street by about 13%. The green planting along the carriageway of 4 city streets in the studied sections practically did not reduce the noise. This was stipulated by the large distances between the trees, the high height of the crowns and lack of a dense protective mass.

Table 3. The research results of acoustic load in the noisiest streets of Kharkiv with the green planting and noise screen

| Place of research         | Kind of protection          | Noise level, [dB] before protective belt | Noise level, [dB] after protective belt |
|---------------------------|------------------------------|------------------------------------------|----------------------------------------|
| Sumska street             | Green planting (1-2 rows)   | 85                                       | 84                                     |
| Pushkinska street         | Green planting (1-2 rows)   | 84                                       | 84                                     |
| Myronosytka street        | Green planting (1-2 rows)   | 80                                       | 80                                     |
| Kloczkostrka street       | Green planting (1-2 rows)   | 94                                       | 93                                     |
| Dynamivska street         | Noise screen                | 80                                       | 70                                     |
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