ARCHIVES OF ACOUSTICS
Vol. 46, No. 1, pp. 147–154 (2021)
DOI: 10.24425/aoa.2021.136568

Research Paper

Soundscapes of Urban Parks in Cities with Populations of Over 100,000 in the Silesian Voivodeship

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(*received August 23, 2019; accepted August 31, 2020*)

The article presents the results of soundscape assessments conducted in urban parks in the Silesian Voivodeship. The Silesian Voivodeship is characterised by a high degree of industrialisation and the greatest population density in Poland. The studies were conducted in the urban parks of all the cities in the voivodeship with populations of over 100,000 citizens. This selection was determined based on acoustic maps that are prepared for cities with populations of over 100,000 citizens as required by law, and on the fact that the role of urban parks is frequently marginalised in the context of city life. The goal of the studies was to define an objective acoustic appeal assessment method for urban parks in city centres. Measurements were carried out in 34 parks located in the centres of 12 cities. A-weighted sound levels L_{Aeq} were determined for 107 measuring points in urban parks and the streets adjacent to them. Differences in the A-weighted sound levels L_{Aeq} were presented for each studied park and the adjacent streets. Minimum and maximum sound values were subsequently determined for each measuring point. Significant differences in the minimum and maximum sound values in given locations were found despite minor differences in L_{Aeq} values. It was also discovered that though parks may often exhibit high A-weighted sound levels L_{Aeq}, there are other factors that influence the appeal of park soundscapes.

Keywords: urban park; soundscape; acoustic comfort; urban noise.

1. Introduction

The article presents an objective method for the assessment of soundscapes in urban parks. Urban noise assessment is performed based on acoustic maps. According to art. 117 of the Polish Environmental Protection Law (2001), an acoustic map must be prepared for an agglomeration with a population of over 100,000 citizens by the local district governor (city mayor). An acoustic map pertains to the discomfort resulting from transport-related noise (road, rail and air transport) and industrial noise. Interventions can be taken based on acoustic maps, as they enable the identification of areas exhibiting exceeded noise values and the quantification of the exposed population (de Paiva Vianna *et al.*, 2015). An acoustic map serves as the basis for the preparation of an environmental protection program against noise for individual cities, which constitutes a selection of priorities and courses of action necessary to reduce the nuisance of noise and to limit its excessive levels within a city.

However, acoustic maps are not a sufficient means of assessing the soundscapes of recreational areas. Acoustic comfort is defined by numerous factors, not only by the level of acoustic pressure alone (Szopińska, 2015). Average A-weighted sound level (L_{Aeq}) values are not sufficient for the purpose of properly characterising a park soundscape. One of the reasons for this is that the acoustic pressure value by itself has no significance with regard to the kinds of sounds present in a park. There are no measuring instruments that would discriminate between pleasant and intrusive sounds (Piechowicz *et al.*, 2013). The objective variable that is the acoustic pressure level must therefore be supplemented with a subjective impression, e.g. "irritation", "discomfort" or "disturbance" (Gozalo *et al.*, 2015). On the other hand, not all the sounds present in urban parks are undesired. Anthropogenic noise can be found in parks, originating e.g. from the activity of children in playgrounds, as well as the sounds of nature, birds or street furniture. The latter includes the sounds of fountains, whose values often exceed permissible noise levels, but which are nevertheless perceived positively by park visitors. Undertaking action with the exclusive intention of noise reduction is not always warranted, as it is based on but one criterion of sound assessment in the environment (Paszkowski, 2013).

Recreational area soundscape assessment is most often performed by combining objective L_{Aeq} measurements with the subjective impressions of individuals who evaluate a given park's acoustic environment. The subjective evaluation is carried out by means of survey and soundwalk methods. A consequence of performing subjective noise evaluation at various scales is the impossibility of making the results uniform and comparing them as far as surveys conducted in different locations and by different researchers are concerned. The surveys may include open-ended questions, such as "describe in your own words"; closed-ended questions, such as "choose one from the list of e.g. loud, quiet, pleasant, unpleasant"; as well as percentage scales from 0 to 100% and numeric scales with ranges of e.g. 1–7. This demonstrates the importance of continued research into new solutions that would enable the performance of soundscape assessments in an objective and repeatable manner in different locations (Miterska, Kompała, 2018). The article presents an attempt at soundscape assessment without the use of surveys.

1.1. Exposure to noise in cities

According to the acoustic map-based soundscape assessment of the Silesian Voivodeship, traffic is the source of the greatest exposure to noise for city residents, whereas industrial noise is the least prominent source. Furthermore, in the case of all the sources of noise, the greatest number of people are exposed to excessive noise within the lowest range of the exceeded values. The total noise in an urban area is the result of the superposition of two basic sources: acoustic background, which is the sum of sounds generated by various anthropogenic activities, excluding transport; and the noise generated by transport. Typically, road transport constitutes the greatest source of noise in a city, and it is rare for any other type of noise to be dominant over it (Lebiedowska, 2005). The environmental protection programs ("Assessment of the acoustic climate of the Silesian Voivodeship on the basis of acoustic maps prepared as part of the third stage of mapping", 2018, "Environmental program for protection against noise for the city of Chorzów", 2015, "Environmental program for protection against noise for the city of Katowice for the years 2017–2022", 2017, "Environmental program for protection against noise for the city of Tychy for the years 2013–2017", 2013) for Silesian cities with populations of over 100,000 demonstrate that the residents of these cities are exposed to noise originating from transport. For Chorzów and Katowice, the environmental protection programs provide separate data concerning exposure to noise originating from tram.

1.2. Urban park soundscapes

An urban park soundscape consists of sounds originating from the park itself as well as those from adjacent areas. Similarly as in a city centre, the greatest noise in a park originates from transport. The source of the most intrusive noise is traffic (Szopińska, 2015). However, the highest rated parks are those with good access to private and public transport (Kothencz, Blaschke, 2017). During the week, most citizens spend their leisure time outdoors only in the vicinity of their place of residence (Maksymiuk, 2005). Previous research found that the perception of soundscapes depended on individual expectations. The park visitors expected certain types of sounds to be present within a specific space. This could be attributed to their prior impressions acquired in similar spaces. There are a certain number of sounds originating from specific sources that are expected to be found in a given environment (Bruce, Davies, 2014). Individuals expect to find respite from noise in a park, whereas it is not necessarily the case as regards other locations (Kang, Zhang, 2010). The key to soundscape analysis is to situate the sound within a specific context, together with the noise and sounds related to the activities taking place at the studied location (Brooks *et al.*, 2014).

The results of prior research (Liu *et al.*, 2014) revealed that park visitors clearly preferred natural sounds over artificial ones, though a relatively high acceptance was found for sounds originating from other humans. Another significant factor that influences the acceptance of a given acoustic environment is the expectation of being able to "control" it. A situation where an individual cannot easily leave a given acoustic environment and has no influence on the source of sounds appears to be conducive to the appearance of irritation. If an individual believes it is possible to control a sound source or a part of it, this results in positive impressions, whereas should the individual feel incapable of controlling the source, then the perception is negative (Bruce, Davies, 2014). Choosing an acoustic environment is possible in the case of large parks with designated areas such as playgrounds or skateparks, and dedicated quiet areas, typically with more prominent vegetation.

Further factors influencing soundscape perception include the sources of sounds present in a park. Pleasant sounds against negative backgrounds result in positive soundscape impressions even when the sound level is high (Yang, Kang, 2005). Water also has an influence on improving soundscape perception. The sounds of running water originating from sources such as streams, fountains or artificial waterfalls are perceived as pleasant by park visitors, even though they contribute to increased L_{Aeq}. These types of sounds are capable of masking other sounds coming from the outside. Ponds and lakes that do not generate sounds also contribute to improved park impressions, as they enhance park space perception by reflecting the sky or the vegetation (Lobo Soares, Bento Coelho, 2016).

2. Method

Acoustic measurements were conducted for all the cities of the Silesian Voivodeship with populations of over 100,000 citizens (Table 1). 34 commonly frequented urban parks located in the centres of 12 cities were selected for the studies. The parks were surrounded by residential buildings, shops, roads and public transport.

Table 1. List of urban parks selected for the conduction of acoustic measurements.

Bielsko-Biała	Park Słowackiego (1)*, Park Włókniarzy (2)
Bytom	City Park (3)
Chorzów	Park Hutników (4), Park Róż (5)
Częstochowa	Park 3 Maja (6), Park Gabriela Narutowicza (7), Park Staszica (8)
Dąbrowa Górnicza	Park Hallera (9)
Gliwice	Park im. Bolesława Chrobrego (10), Park Chopina (11), Park im. Adama Mickiewicza (12)
Katowice	Park Bogucki (13), Kościuszko Park (14), Park Powstańców Śląskich (15), Silesia Park (16)
Ruda Śląska	Park Dworski (17), Park im. A. Mickiewicza (18), Park Młodzieży (19), Park Tuwima (20)
Rybnik	Park na Górce (21), Park nad Nacyną (22), Park Tematyczny nad Nacyną (23)
Sosnowiec	Park Kruczkowskiego (24), Park Sielecki (25), Park Środula (26)
Tychy	Park św. Franciszka z Asyżu (27), Park Jaworek (28), Park Łabędzi (29), City Park (30), Park Niedźwiadków (31), Park Północny (32)
Zabrze	Municipal Botanical Garden (33), Park im. Poległych Bohaterów (34)

* The park numbers correspond to the numbers in Figs 1–12.

The measurements were conducted in July–September 2018 and May 2019 (Zabrze, Ruda Śląska). The measurement date was adopted based on the necessity to perform the measurements under similar conditions: with full foliage, functioning fountains and people relaxing in the parks. The measurements were conducted during workdays, and there were no cultural events taking place in the parks during the measuring period.

The measurements were taken by day, under favourable weather conditions. The acoustic measurements were carried out using the direct method. The measuring time at each measuring point was 20 minutes. The measuring points were located in various soundscapes and in different parts of the parks. The measuring points were established in the main alleyways, in the vicinity of monuments, playgrounds, fountains and bicycle lanes, as well as in less frequently visited park areas. The measurements at each point encompassed the determination of the A-weighted sound level L_{Aeq} and the minimum and maximum sound levels in dBA.

The average L_{Aeq} as well as the minimum and maximum acoustic pressure levels in dBA were simultaneously determined in the city streets adjacent to the studied parks. Public transport, people, shops and other unidentified sounds from the urban acoustic background constituted the sources of noise in the vicinity of the parks. Measurements were taken in a total of 107 measuring points.

3. Results

According to Annex 5 of the government ordinance concerning land and property registration (Ordinance of the Minister of Administration and Digital Affairs, 2013), urban parks are classified as recreational and leisure areas. The permissible average A-weighted daytime sound level L_{AeqD} for recreational areas is only 3 dBA lower than the permissible L_{AeqD} for strict centre areas in cities with populations of over 100,000 residents (Announcement of the Minister of Environment, 2013). The first stage of the measurements involved the determination of L_{Aeq} in the parks and the streets adjacent to the parks. The minimum and maximum L_{Aeq} values in the vicinity of a park (b) and within a given park (a) are presented on diagrams (Figs 1–12).

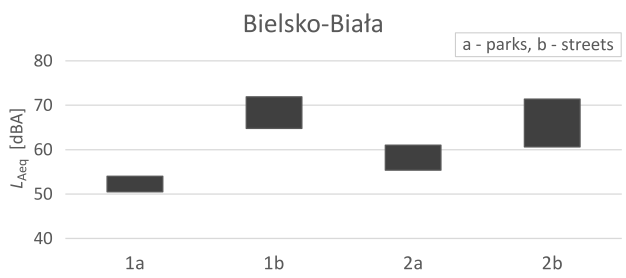

Fig. 1. L_{Aeq} in the parks and adjacent streets in Bielsko-Biała.

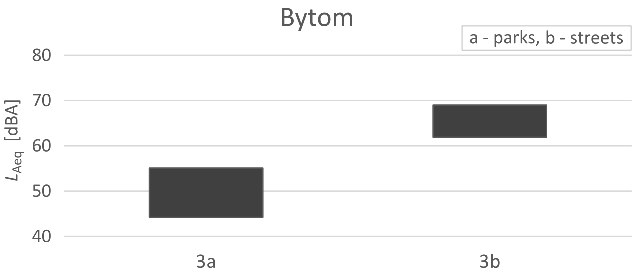

Fig. 2. L_{Aeq} in the parks and adjacent streets in Bytom.

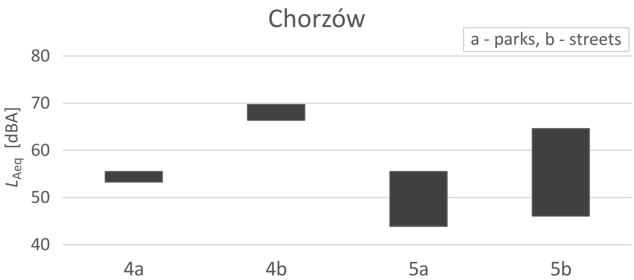

Fig. 3. L_{Aeq} in the parks and adjacent streets in Chorzów.

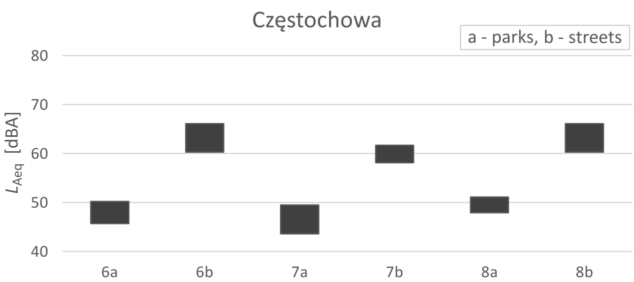

Fig. 4. L_{Aeq} in the parks and adjacent streets in Częstochowa.

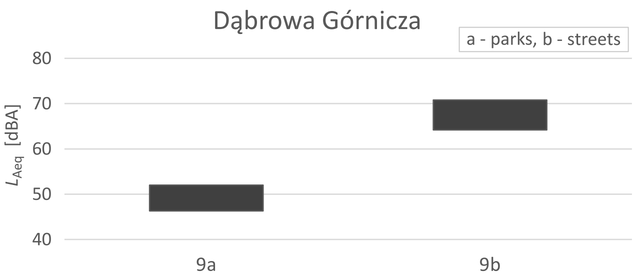

Fig. 5. L_{Aeq} in the parks and adjacent streets in Dąbrowa Górnicza.

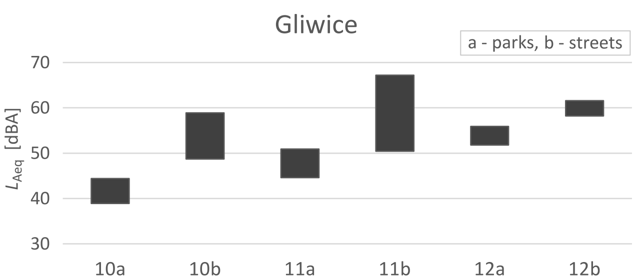

Fig. 6. L_{Aeq} in the parks and adjacent streets in Gliwice.

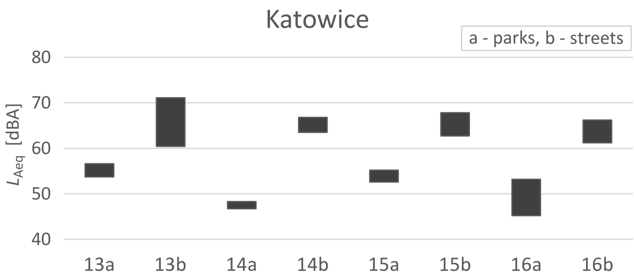

Fig. 7. L_{Aeq} in the parks and adjacent streets in Katowice.

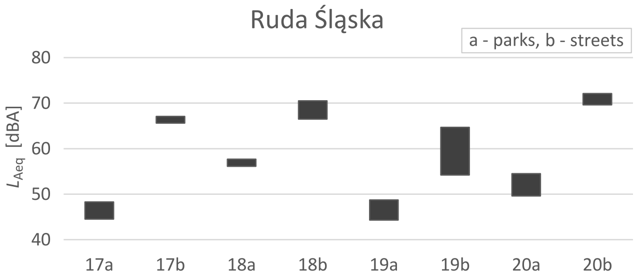

Fig. 8. L_{Aeq} in the parks and adjacent streets in Ruda Śląska.

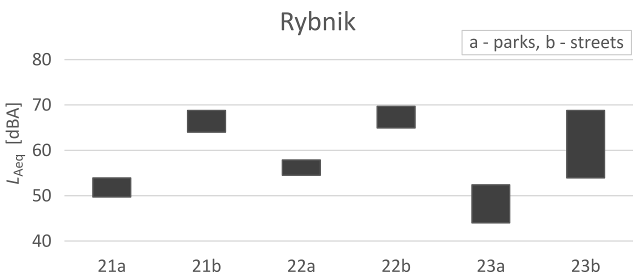

Fig. 9. L_{Aeq} in the parks and adjacent streets in Rybnik.

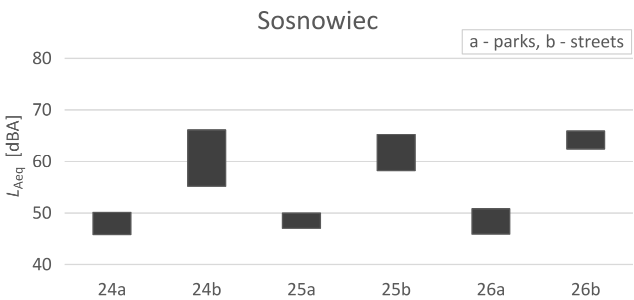

Fig. 10. L_{Aeq} in the parks and adjacent streets in Sosnowiec.

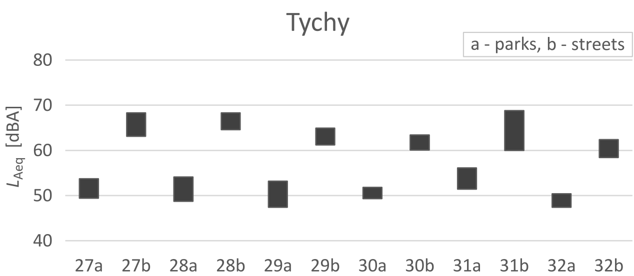

Fig. 11. L_{Aeq} in the parks and adjacent streets in Tychy.

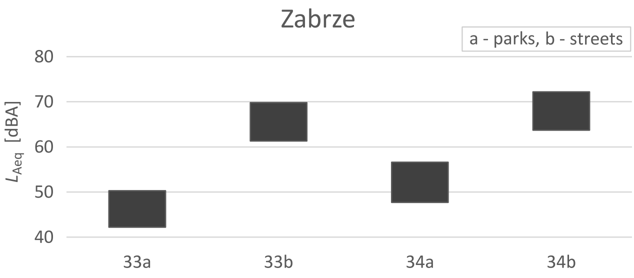

Fig. 12. L_{Aeq} in the parks and adjacent streets in Zabrze.

As expected, the average A-weighted sound level L_{Aeq} measured in the parks was lower than the L_{Aeq} in the vicinity of the parks. The difference between maximum and minimum L_{Aeq} in a given park was a result of the specific park characteristics – parks with playgrounds or fountains exhibited greater differences in L_{Aeq} between individual points compared to parks that lacked diverse areas. The Municipal Botanical Garden in Zabrze is an example of such a park. Though generally characterised by low L_{Aeq}, it also included louder areas such as café premises or a playground. The second factor influencing L_{Aeq} was a park's location within the city. Some of the parks were located by major roads that considerably increased L_{Aeq} in certain parts of the parks. Examples include Park Róż in Chorzów or Park Łabędzi in Tychy. As for streets, the L_{Aeq} value was dependent on the intensity of traffic. Some of the streets were major roads, whereas other parks were surrounded by intercity roads, where speed limits, traffic lights and restrictions to truck access resulted in lower L_{Aeq} in given measuring points. The greatest differences in L_{Aeq} for areas adjacent to the parks were registered in the vicinity of Park Róż in Chorzów, Park Chopina in Gliwice and Park Tematyczny nad Nacyną in Rybnik as a result of the presence of major roads at the borders of the parks.

In the majority of cases, the difference in average L_{Aeq} was lower for the parks themselves than for the adjacent streets. Parks with diverse infrastructure were the exception, e.g. Silesia Park in Katowice or the City Park in Bytom, as well as extensive parks with major roads running on one side, e.g. Park Łabędzi in Tychy.

The next stage of the studies involved the analysis of the difference between the maximum and minimum level of acoustic pressure in given measuring points in the parks and adjacent streets.

The differences between maximum and minimum acoustic pressure levels for the majority of the parks were lower than the differences between the maximum and minimum values for measuring points in the adjacent streets. The greatest differences within a single park were registered in the vicinity of a playground in Park Tematyczny nad Nacyną in Rybnik, which could be attributed to factors such as the gravel bed in the playground and the numerous devices for physics-based experiments available to the children. High differences were also registered in urban park playgrounds found in other cities. The lowest differences were obtained in park areas located far away from major roads, where the sounds generated by traffic melded into a uniform noise, and by bodies of water with uniform flow, e.g. by the waterfall in the Bytom City Park.

The greatest differences between maximum and minimum values measured in streets adjacent to the parks were registered in Ruda Śląska on Pokoju street by Park Dworski. The street is characterised by pauses in traffic and the occasional movement of trucks and buses. Another location exhibiting high differences between maximum and minimum sound values was Aleja Korfantego in Zabrze, part of which runs over Park im. Poległych Bohaterów. The high local variations in sound levels can be attributed to traffic lights. Similar variations were registered on Księdza Jerzego Popiełuszki street in Częstochowa, which is crossed by groups of pilgrims.

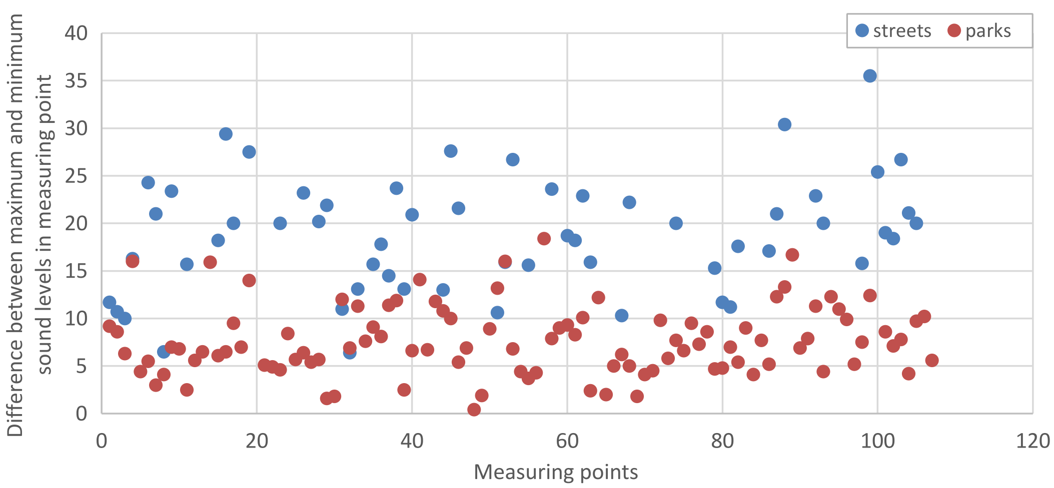

Fig. 13. Differences between maximum and minimum sound levels in measuring points in urban parks and adjacent streets.

4. Discussion

According to standard ISO 12913-1, a soundscape is an acoustic environment as perceived and/or understood by a person or people in context. The acoustic environment is the total sound perceived from all sources, and the context includes the interrelationship between person and activity and place, in space and time.

The conducted studies demonstrated that the A-weighted sound levels in urban parks located in city centres are high. Observations of the number of people who visit all the studied parks reveal that, despite the high L_{Aeq} values that are frequently found there, city dwellers eagerly spend their time in metropolitan green space to experience relief from urban noise. The reason for this is that L_{Aeq} in itself does not constitute a sufficient criterion for soundscape assessment, as the sounds must be evaluated within a certain context. Local administration bodies are obliged to perform certain tasks as part of the environmental management process. One of these tasks is the obligation to prepare acoustic maps for cities with populations of over 100,000 residents and to undertake remedial action should permissible sound values be exceeded. It could perhaps be assumed that increasing the number of urban parks would result in the improvement of the acoustic environments in city centres. However, city morphology has greater influence on urban noise than the number of parks. Each city has its own dynamics and character, and linear urban design results in louder cities compared to radial design, due to the greater number of long streets (Margaritis, Kang, 2016). Research by other authors (Margaritis, Kang, 2017) also reveals that the number of parks does not have a direct influence on urban noise. For example, Amsterdam seems more quiet than Brussels; but it is Brussels that exhibits a higher ratio of green space coverage. The attractiveness of urban park acoustic environments is influenced not only by the level of acoustic pressure, but also by the human attitude towards the sound source. Although they contribute to higher average L_{Aeq}, street furniture elements such as fountains are perceived as visually and acoustically attractive and serve to improve the general impression of a park. Interacting with nature is also a source of comfort in and of itself, and parks with higher ratios of green space are more attractive to the visitors (Kothencz, Blaschke, 2017).

The studies presented in this article demonstrate that the variations between quiet and loud sounds are lower in urban parks than in the adjacent streets, and they are also independent of L_{Aeq}. This offers the impression of a more attractive acoustic environment. The reason for this is that human attention is drawn to sudden noises, whereas sounds that are stable over time are easier to ignore. It is easier for the park visitors to disregard the constant background noise, and to relax and discern pleasant sounds, such as birdsong.

The article demonstrates why acoustic maps are not a sufficient tool for the assessment of sounds present in urban parks. It is also an attempt at developing a new acoustic environment assessment method for urban parks that would enable the comparison of various park soundscapes without the necessity of conducting surveys among park visitors.

5. Conclusions

The article presents an urban park soundscape assessment method based on acoustic measurements, without the conduction of subjective evaluation by means of surveys. The method is based on the L_{Aeq} value determination in urban parks and their vicinities, and on determining the differences between maximum and minimum sound levels in parks and adjacent streets. The influence of urban sounds on park soundscapes has been demonstrated as well.

Similarly as in the case of acoustic maps, publications on the topic of acoustic environment analysis for recreational areas adjacent to urban areas are primarily focused on the acoustic pressure level and the influence of dBA on the perception of a given location's soundscape. The purpose of an acoustic map is to determine whether boundary values have been exceeded, and its focus is on citizen exposure to noise in dwellings, educational facilities and places of employment. It pertains to noise protection and the negative influence of noise on the human body. The sounds present in parks can include anthropogenic noise, e.g. related to the activity of children in playgrounds, but also the sounds of nature, birds, street furniture such as fountains, or artificial brooks, whose levels often exceed permissible noise limits in the first place. Yet despite this, city dwellers nevertheless seek refuge from street noise in urban parks. An urban park soundscape assessment should not be based on L_{Aeq} alone, and each acoustic environment should be examined from a number of perspectives. Human attention is not drawn to specific sounds when the differences in acoustic pressure between individual sounds in a given environment are lower. The possibility of choosing which part of the park and what acoustic environment an individual wishes to be exposed to already has beneficial influence on general well-being, which is further modified by the individual's attitude towards the sources of sound in the immediate vicinity. An acoustic background with minor sound level variations contributes to a more positive soundscape assessment, as one's attention may be drawn to what can be seen while taking less notice of what can be heard, but simultaneously making it easier to discern the pleasant sounds of nature. Finally, studying different measurable soundscape parameters contributes to increased accuracy during the comparison of selected urban parks between one another.

Acknowledgements

This work was supported by the Ministry of Science and Higher Education of the Republic of Poland (Statutory activity no. 103 5502 8-171).

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