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A Note on Variation of the Acoustic Environment in a Quiet Residential Area in Kobe (Japan): Seasonal Changes in Noise Levels Including COVID-Related Variation

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Abstract: This communication compares the previously reported results of the acoustic environment, mainly noise levels at a fixed point, in a quiet residential area in Kobe, Japan, under the declaration of the COVID-19 state of emergency in May 2020 with the results of two follow-up studies in the same area: subsequent follow-up noise measurements in June and July–August 2020, and the present results of measurements in September–October 2020. The results of the comparison among the above three measurements suggest that noise levels were lower during September-October 2020 than during the declaration of the state of emergency in May 2020. In the period from May to October 2020, the noise level was significantly higher in July and August of the same year due to the sound of cicadas, which are common in this area. This suggests that it is difficult to set the target values of the acoustic environment planning by referring to the low noise level at lockdown or similar measures in areas with large seasonal variations in acoustic environment. Although many case studies are necessary to obtain appropriate target values, one case study is presented in this communication to illustrate an example and discuss its difficulty.

Keywords: acoustic environment; noise level; residential area; seasonal variation; COVID-19 pandemic; state of emergency in Japan

1. Introduction

Not only in cities, but in all places, the sound environment is rarely constant and unchanging throughout the year. In other words, it is clear that the sound environment fluctuates over time, and, thus, throughout the year depending on seasonal variations, people's activities and social activities. In particular, if an area is subjected to seasonal variations in temperature and weather conditions, the sound environment is also likely to be affected by the ecology of plants and animals accordingly. However, in reality, it is likely that the sound environment is affected by seasonal variations in human activity in the central part of the city, which is an artificial space. These changes and transitions in the sound environment have been discussed in many research works, e.g., [1,2].

In 2020, the COVID-19 pandemic led to lockdowns or similar measures in many countries around the world, and the resulting changes in the sound environment, particularly a reduction in noise levels, were reported [3–6]. In [6], the change in urban soundscape is also reported. Significant reductions in noise levels were observed in the vicinity of usually bustling urban centres and mega-infrastructures due to lockdowns [7]. On the other hand, in some reported cases, no significant differences were found in usually quiet residential areas [8]. Aletta et al. provided a detailed discussion of the sound environment in residential areas and reported cases where significant changes were observed in some locations [9]; the same paper analysed the impact of lockdown based on measurements in 12 locations in London, and the impact ranged from small to quite large. Asensio et al. [10] reported a detailed analysis of changes in noise levels due to COVID-19 lockdown in Madrid, Spain, which ranged 4 to 6 dBA by measured results of L_d, L_e and L_n. Also, they reported level change in a day and week.

Naturally, once the lockdown is lifted, economic, social and life behaviours will gradually return to normal, and in the process, the sound environment is likely to change as well. The author conducted a follow-up study on changes in the sound environment in Japan after the state of emergency declaration was lifted, and summarised the results of the next two months [11]. The results suggest that the noise level may have been rather high immediately after the state of emergency declaration was lifted, but in any case, the sound environment changed on a monthly basis. In many cases, the noise level was low and quiet during the lockdown or similar measure, but once it was lifted, the sound environment was expected to approach the pre-lockdown state, i.e., the noise level will gradually increase: it is preferable to plan for a return to a quieter and more comfortable level than before the lockdown [9]. That is, it is possible to return to a "normal" sound environment in the area, but more than that, it is also possible to "improve" the sound environment by achieving a quieter state. In this case, we need to get a clear idea about setting goals to reach. In addition, if the lockdown impact is small in an inherently quiet area, it may be difficult to obtain a clear "improvement" target. In addition, in the case of seasonal variation, it is expected that it will be difficult to apply the concept of which state to return to.

Here, we report a case study in a quiet residential area in Japan, a country with four distinct seasons. As mentioned earlier, a number of studies in Japan have reported seasonal changes in soundscapes [1,2]. Soundscapes at Japanese tourist attractions were also examined in detail in studies by Lee et al. [12,13]. Among them, a case study at Fushimi Shrine [13] presents the results of an analysis of a unique sound environment by applying frequency analysis, with the cicada sound being loud and dominant.

Research works relating to seasonal variations of acoustic environments are carried out in the context of multimodal evaluations of the environment. Jin et al. [14] discussed the effect of the interaction between source type and sound level on acoustic, thermal and overall subjective evaluation in laboratory experiments simulating seasonal changes of the environment. D'Alessandro et al. [15] considered the influence of visual and other aspects on evaluating the soundscape at a university campus in the context of design and quiet areas. The same paper includes a seasonal comparison between summer and winter. Both provide the aspect of seasonal change in soundscapes and its subjective evaluation in general. Cerwen [16] studied extensive soundscape studies on Japanese gardens by observation and video-recording in situ, and analysed that there was a seasonal effect relating to a natural animal (frog) sound on the soundscape evaluation. Similar effects depending on natural sound or each season should be observed in various places.

In contrast, this note does not discuss such a multimodal effect, but shows the results of a follow-up investigation following the previous cases investigated by the author [8,11]. It rather illustrates that there are seasons when the noise level is lower than it was during the declared state of emergency and seasons when it is significantly higher than it is with a natural change of the environment only. This paper discusses the fact that it is not easy to define the "normal" sound environment because the area under investigation is a quiet residential area with a relatively good natural environment and the seasonal variations are relatively large.

2. Methodology

The measurements were conducted at the same location, Fukae-minami area, Eastern edge of the city of Kobe, Japan, as previously reported [8,10]. Figure 1 shows a map of the measurement points and their surroundings. The measurements were conducted during and immediately after the declaration of a state of emergency in May, about one month after the lifting of the state of emergency (in June), and in July and August 2020. The results were discussed in detail in previous reports [8,11]. In [8], the measurements were made mainly at the fixed point marked with a black star in Figure 1; however, some additional points marked as (1) to (6) to illustrate the acoustic environment of this area. Regarding the point marked with white star, it was only used to increase of noise level by people's activities in open space, and not used in [11]. In [11], the results at the fixed point were mainly discussed, though recorded soundwalk data in the route including points (1) to (6) were shown. Note that most construction sites marked with X were finished and closed in the period of the present measurement.

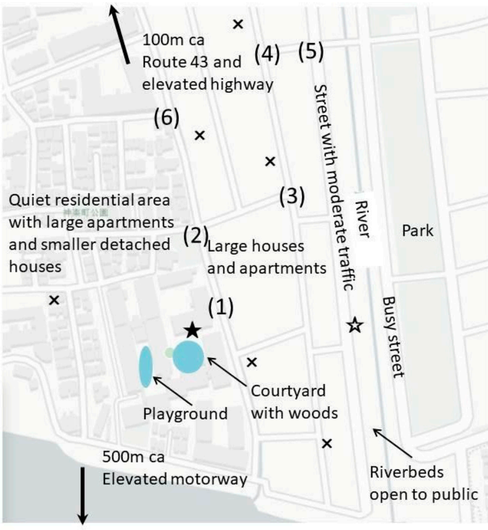

Figure 1. Map of measurement points and surrounding area (Fukae-minami area, Eastern edge of Kobe, Japan). In the measurements in September–October, only the point marked with a black star was used; it is on the second-floor balcony of a block of flats and faces the courtyard with woods and surrounded by other apartment buildings. The playground is near the measurement point but there is a building shielding it. The marks "X" indicate construction sites that were working in May and June, but after July most of them were finished and closed.

The present measurement was conducted between 27 September to 4 October, 2020, and was divided into dawn (04:00–06:00), morning (07:00–11:00), afternoon (12:00–16:00) and early evening (17:00–19:00), with several measurements per day for each time period. The average values were taken for each time period. Measurements were also taken at midnight. The measured value is the A-weighted continuous averaged sound pressure level L_{Aeq} (T = 1 min) by using a standardised sound level meter (RION, NL-27, Class 2). Although it has been proposed to use L_{Aeq} and the like as long time averages to measure and evaluate the effects of lockdown [6], the author has consistently used short time averages (L_{Aeq}, T = 30 s or 1 min) [8,11], and this seems to be more suitable to describe the hourly variation in each day. Perceived sound sources were noted during the measurement by the surveyor (the author). In the recorded soundwalk, NoiseCapture's "Description" page for each measurement, in which main sound sources can be recorded, was used.

As an auxiliary measurement, recorded soundwalk was conducted in the neighbourhoods around and near the measurement points. For this, the NoiseCapture application [17,18] was installed and used on an Android Alldocube iPlay 7T and Teclast P80X tablets (set to T = 30 s). The accuracy of the application was calibrated with a Class 1 sound level meter prior to use, and the measurement accuracy of the application was verified [8]. Soundwalking continuously records L_{Aeq} while walking around a city block and displays it on a map or aerial photograph. This allows us to get an overview of the sound environment of the entire city block, which is useful for comparison.

In order to discuss the seasonal change of the acoustic environment, the composition of perceived sound sources was also recorded (except that for June) and analysed by classifying the perceived sound sources and their frequency of observation to find a dominant source that characterised the acoustic environment in each measurement result.

3. Results and Discussion

The present results in September–October at the measurement points are shown in Figure 2 together with the results of the previous report: May (both during the state of emergency and after its cancellation), June, July–August. Note that the results were averaged in each time range in the graphs shown. The noise level during July–August was outstandingly high, but this was due to the sound of cicadas, which is common in this area and is not heard except in summer. Including this, the trend based on the time of day is roughly the same: a general trend of rising in the morning and afternoon and decreasing towards night. This trends were similar to the previous results [8,11]. However, the level was extremely high from July to August, and although the sound environment was "normal" for this time of year, it was unique compared to other times of the year; the comparison is shown in Figure 3.

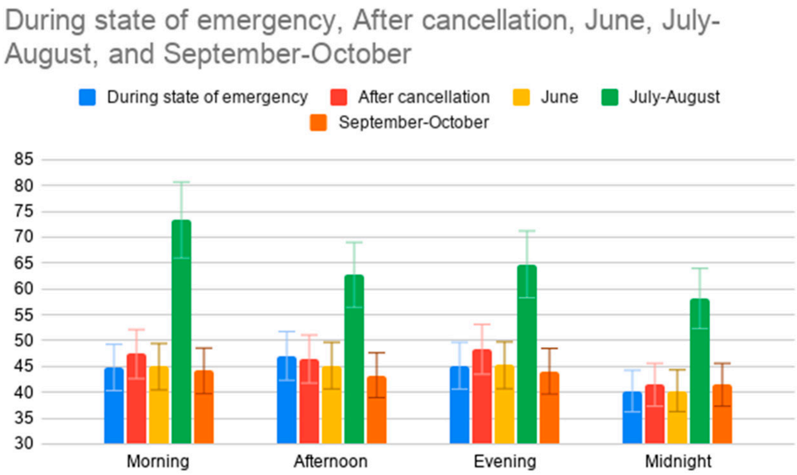

Figure 2. Comparison of morning, afternoon, evening and midnight noise levels (L_{Aeq}) from measurements during and after state of emergency in June, July–August and September–October. As can be seen clearly, levels in July–August were much higher than other times. This is because the cicada sound is dominant in the summer in this area. (The number of measurement: N = 350).

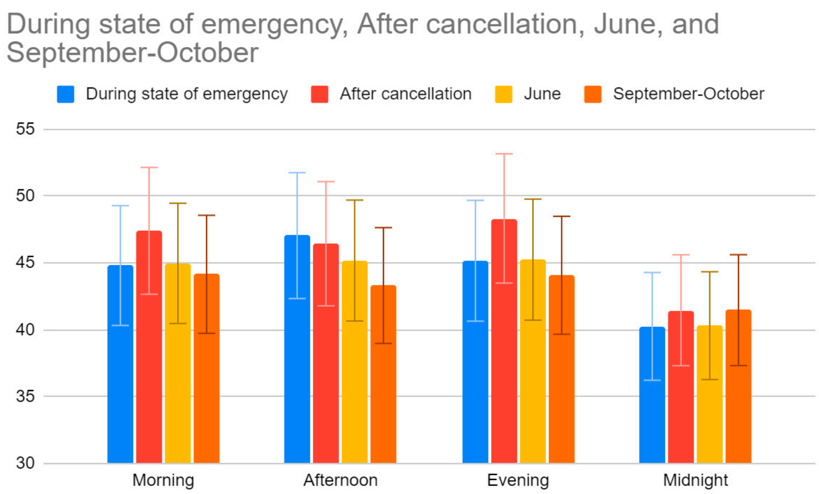

Figure 3. Same comparison as in Figure 2, but here the results from July–August are omitted for a detailed comparison of the measured results during and after state of emergency in June and September–October. (The number of measurement: N = 292).

A one-way analysis of variance (ANOVA) was carried out to the five sets of the measured results (before averaging): two sets in May (during the state of emergency and after its cancellation), June, July–August, and September–October. The result was $F(4, 350) = 135.9$, $p = 6.42 \times 10^{-70} < 0.01$, therefore, there is a significant difference among these five groups. Furthermore, when the data from July-August measurement, $F(3, 292) = 19.16$, $p = 2.28 \times 10^{-11} < 0.01$. Therefore, even if extremely high levels in July-August was excluded, there is a significant difference among the four groups. Note that these ANOVA were performed using all measured data without classifying them into time categories in the graphs.

As shown in Figure 3, there was a difference between May (both during the state of emergency and after its cancellation), June and September-October, and the trend was almost the same in all three months. In order to specify the significance of the low levels in September-October, *t*-tests between two groups, May and September-October, and June and September-October, were carried out. The results of the *t*-test indicate that the noise level was significantly lower and quieter in September–October than in the May and June months: $t(163) = -2.77$, $p = 0.003$ between June and September–October and $t(141) = -5.66$, $p = 0.00000004$ between May (both during the state of emergency and after its cancellation) and September–October. Therefore, it cannot be said that the area was particularly quiet during the state of emergency than at other times.

For reference, examples of soundwalking measurements by NoiseCapture [17,18] in the vicinity of the measurement point for July and September are shown in Figure 4. The plot is shown in colour based on dBA: red and purple indicate high levels, and green and blue are lower levels. The maps indicate that the city blocks that had extremely high levels in July due to the contribution of cicada sounds (mostly red and purple) were very quiet in autumn (mostly green and blue). The sound of cicadas was extremely loud in July and August; although we did not have measured data before 2019 in this area, it was not a special year as we experienced this loud sound every year. Therefore, we can say that this was a "normal" sound environment.

(a) With cicadas sounds (09.30, 22 July 2020) (b) With no cicadas sounds (09.30, 6 November 2020)

Figure 4. Soundwalk recording data taken by NoiseCapture app around the measurement point: (**a**) Late July 2020, when cicadas were most active and their sound was the loudest. Purple zone is around or over 80 dBA. (**b**) Early November 2020, when no cicada sound was heard. In most areas the level was around 40–45 dBA. Both measurements were conducted at the same hour of the day, 09:30.

The results show that the sound of cicadas is dominant in the summer in this region. On the other hand, there is no significantly dominant component in the autumn results.

Regarding the composition of the acoustic environment, perceived sound sources are compared in Figure 5 (except for June, when only the noise level was recorded). Most construction sites shown in Figure 1 were closed, although a few sites were still in work, but the noise from them did not contribute significantly. The tendency of the frequency of observation was not much different for May (during and after the state of emergency) and September–October, but that of July–August was totally different from the others. The cicada sound was most frequently heard and quite dominant in noise level from morning to evening, and masked most sounds from other sources. Road traffic noise from main traffic, which is more than 200 m distant, was almost always audible, though faint, in other seasons, but in July–August it was masked during the daytime and only heard in the early morning and late at night. Thus, the acoustic environment in this area is dominated by the cicada sound during the daytime in summer.

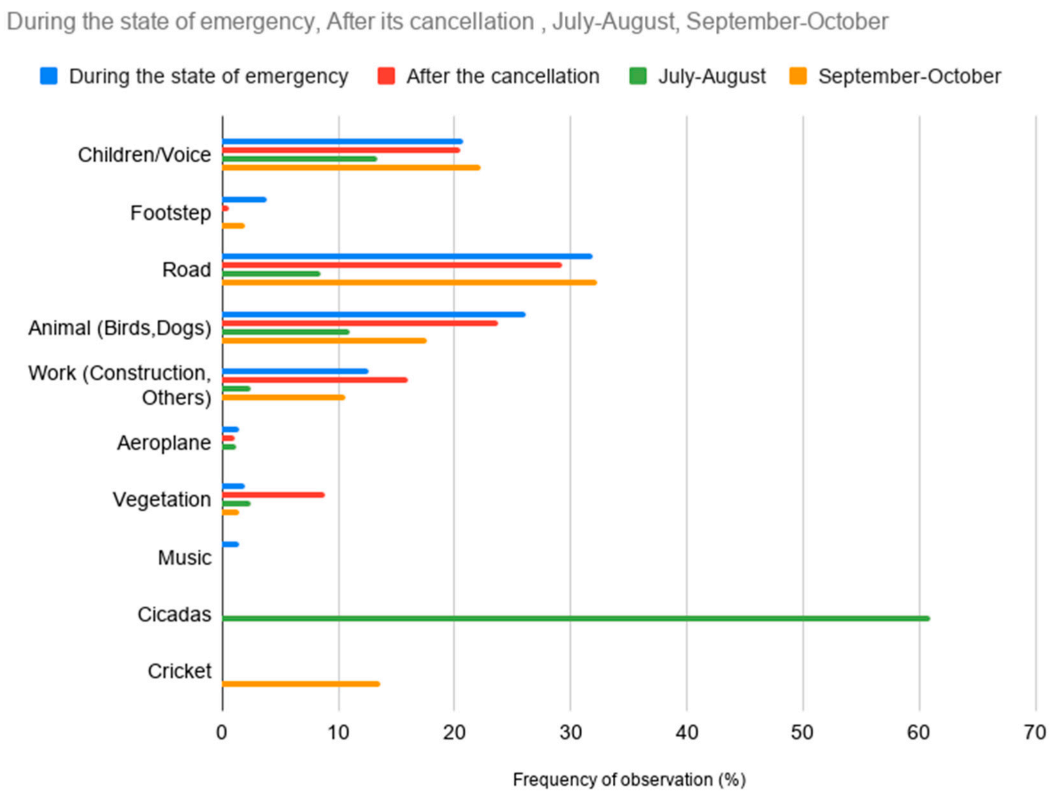

Figure 5. Composition of perceived sound sources. Percentile frequencies of observation from measurements perceived by the surveyor (the author) in May (during the state of emergency and after its cancellation), July–August and September–October are categorised and plotted.

Cicadas become inactive and decrease in late summer, and in September most cicadas are usually gone. Therefore, in the September–October measurement, cicadas were not heard. Instead, during this season crickets and autumn bugs are active every year. They make sounds but the level is not high, and their sounds are usually considered pleasant. These bugs are nocturnal and inactive in the daytime; their sound is heard mainly in the evening. This is why the frequency of hearing the sound was not very high; however, it is in a sense dominant in the evening in autumn and certainly characterises the acoustic environment, more specifically the soundscape, in autumn in this area. Similar phenomena may take place in various places, e.g., during the lockdown it is reported that natural sounds that had been masked by noises could be heard and produced a soundscape different from usual [6]. In the area studied, as there is no significantly large noise; natural sounds could be more easily heard.

For additional information to give a general idea about the acoustic environment of this area, the noise levels on the residential block next to the surveyed area is briefly mentioned. In the measurement in May 2020 (during the state of emergency), some measurements of noise level (L_{Aeq}, T = 30 s) were made at the points (1) to (6) in Figure 1 [8]. The results ranged from 45.7 to 64.6 dBA [8]. For comparison, the recorded soundwalk results are shown in Figure 6. Since this block had larger traffic volume than the current surveyed area, the noise levels are higher than the current survey area. However, the levels are in almost the same range as the measurement during the state of emergency.

This comparison is also considered to give an inference that the acoustic environment during the state of emergency is not much different from that in September–October 2020 which is quite "normal".

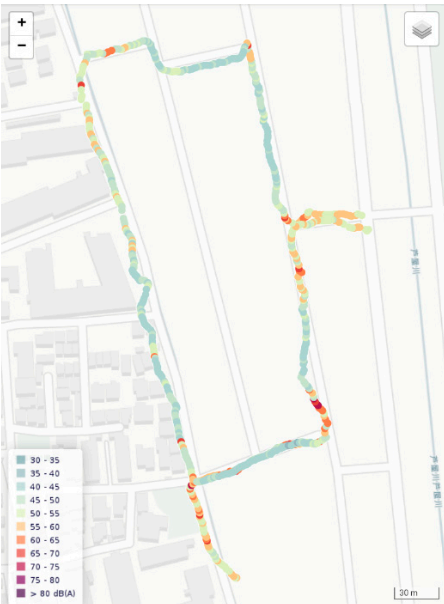

Figure 6. An example of recorded soundwalk results in the block next to the current measurement area (at 10:00–10:15, on 27 October 2020). From this map noise levels were ranged from 35 to 65 dBA as plotted in light blue to red. Most red plots (>60 dBA) were caused by the occasional passing-by of vehicles. This results suggests that the range of the noise levels in this area did not differ much from those measured during the "state of emergency" in May 2020 [8]. Higher noise levels (marked in red) were mainly the occasional passing-by of vehicles. Moderately high level (marked in yellow) were mainly voices and footsteps of passers-by, or cars stopping at a traffic signal.

4. Concluding Remarks

Based on the author's previous report and the results of a follow-up study [8,11], this paper presents seasonal changes in environmental noise levels in a residential area and discusses how to think about the "normal" sound environment.

As an example, the results of noise level measurements in a residential area where a significant increase in noise levels is usually observed in summer were examined. In the non-summer months, the noise level was low, especially in some seasons, when it was lower than the level during the COVID-19 state of emergency declaration. In the area studied in this present work, the noise level during the state of emergency declaration is not necessarily considered to be particularly suitable as a target value for acoustic environment planning.

Even if there was a significant increase in noise levels during the summer months in previous years, the high noise levels are also considered "normal". One idea would be to exclude the high noise level in summer and to maintain average values over the rest of the seasons. Therefore, in an area where the seasonal effect of noise levels is significant, there should be some discussion of how to define a target acoustic environment. In this paper, an example in a particular location was presented where data from averaged noise levels, or the levels in the periods of lockdown or similar measures, are difficult to be used as a reference.

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