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NOISE SOURCE ANALYSIS THROUGH ENVIRONMENTAL NOISE MEASUREMENTS

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ABSTRACT

Exposure to excessive noise is linked to significant adverse effects on human health, including stress, sleep disturbances, and reduced quality of life, particularly in residential areas near commercial or industrial zones. This study focuses on analyzing the noise components emitted by various sources located on the rooftop of a hypermarket. The aim was to measure and identify the noise levels generated by the operating machinery, such as air-conditioning systems, cooling units, rooftop ventilation, transformers and compressors, which could impact the nearby environment, particularly the residential buildings located in front of the examined hypermarket.
Field noise surveys were carried out in the summer period during daytime and night-time to measure noise levels under operational conditions. These measurements were followed by thorough frequency spectra investigations utilizing Fast Fourier Transform (FFT) analysis, which helped identify the most significant noise contributors. While the study provided clear insights into the operational noise impacts during the summer, winter-specific noise sources, such as boilers were excluded due to seasonal constraints.
The findings serve as a foundation for further mitigation measures, including re-evaluation during winter operation to address potential regulatory noise exceedances and noise complaints.

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Keywords: *noise measurements, environmental noise, spectra analysis, noise exposure, case study*

1. INTRODUCTION

Exposure to high noise levels can cause mental and physical adverse health effects [1]. It is linked with long-term risks of cardiovascular illnesses [2], such as heart attacks or hypertension. Moreover, excessive prolonged noise exposure affects work and educational environments, overall cognition, communication, and it weakens our attention [3-4]. Noise from industry increases the probability of residents nearby to suffer from mental illnesses [5]. Therefore, different mitigation measures to reduce the hazard caused by industrial noise were evaluated by many researchers [6]. For instance, sound absorption and insulation enclosures were designed to reduce the noise emissions of transformers [7], noise reduction of around 20 dBA was obtained by building noise barriers around a metallurgical factory [8], and acoustic metamaterials that could be used to increase the sound insulation performance for a better acoustic building design [9]. However, implementing noise reduction measures usually demand significant manpower and financial resources [6]. Therefore, this study utilized the Fast Fourier Transform (FFT) method through environmental noise measurements to analyze the spectral emissions of various equipment. The results were compared with the spectral emissions at the sensitive receptor to identify the most significant noise contributors. The findings are expected to provide a basis for further mitigation measures to reduce noise levels from the major contributors.

2. MATERIALS AND METHODS

2.1 Problem Overview

Residents of a dwelling situated across the street from a hypermarket were disturbed by the noise generated from the machines operating both within the hypermarket, and on its rooftop, despite the presence of a 3-m noise barrier. The study was limited to identifying the most contributing noise sources to the reported annoyance rather than to evaluate compliance with regulatory limits. Figure 1 below illustrates the location of the study area.

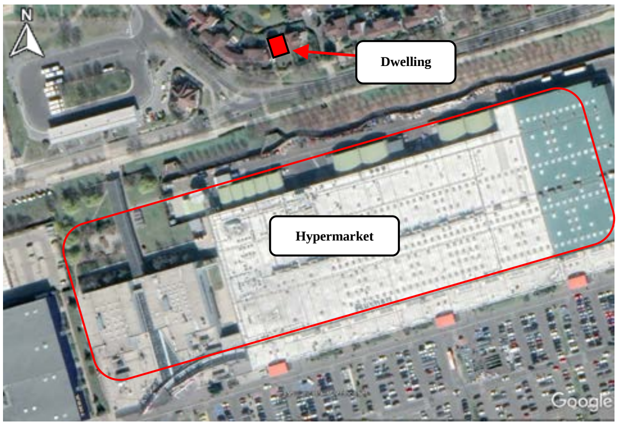

Figure 1. Study Area Overview.

2.2 Methodology

To assess the noise levels and identify the dominant noise sources accurately, two Class 1 Sound Level Meters (SLM) were utilized. One SLM was positioned at 2 meters from the façade of the Dwelling, referred to as Sensitive Receptor (SR) and at a height of 1.5 m from the ground level, according to ISO 1996 series [10-11], to measure the noise levels experienced by the residents, while the second SLM was placed around the machinery operating within the Hypermarket boundary, such as air-conditioning systems, cooling units, rooftop ventilation, transformers and compressors. This simultaneous measurement at both locations was conducted during daytime and nighttime and allowed for direct correlation between the noise contributions of specific machinery and their impact on the residential area. Fast Fourier Transform (FFT) function was enabled during the measurements to provide a full overview of the spectrum at both locations for further analysis.

Additionally, the study took place during the summer period. Therefore, winter-specific noise sources, such as boilers were excluded due to seasonal constraints.
Table 1 summarizes the description of each measurement point depicted in Figure 2 below.

Table 1. Measurement Points Description.

MP ID.	Noise Source Description	Operation (Day/Night)*
R0	Cooling Unit 1	I/I
R1	Transformer 1	C/C
R2	IT Equipment Noise 1	C/-
R3	Exhaust Chimney 1	C/-
R4	Exhaust Chimney 2	C/C
R5	Outdoor AC Unit	C/-
R6	Air Conditioner 1	C/-
R7	Air Conditioner 2	C/-
R8	Exhaust Chimney 3	C/C
R9	Cooling Unit 2	C/-
R11	IT Equipment Noise 2	C/-
R12	IT Room Ventilation	C/-
R13/R14	Cooling Unit 3	C/C
R15/R16	Cooling Unit 4	C/-
R17	Waste Collection Area	C/C
R18	Manual Pallet Truck	C/-
R19	Ice Maker Outdoor Unit	C/C
R20/R33	Transformer 2	C/C
R21	Press Machine	I/-
R22/R34	Air Cooler	I/I
R23	Cooling Unit 5	I/-
R24	Air Conditioner 3	C/C
R25	Fans	C/C
R26/R39	Exhaust Chimney 4&5	C/C
R27	Rooftop Fresh Air Fan 1	C/C
R28	Rooftop Fresh Air Fan 2	C/C
R30/R37	Pumps	C/C
R31	Exhaust Chimney 6	I/I
R40/R41	Compressor Venting	I/I
R42/R43	IT Equipment Noise 3	C/C

*C = Continuous, I = Intermittent

Figure 2. Measurement Point Locations.

Then, the results obtained from all measurement points were plotted in charts utilizing FFT analysis and compared with the results obtained at the Sensitive Receptor (SR) during both daytime and nighttime to identify any correlations in the measured spectra. In all charts, the right Y-axis represents the noise levels (dB) of the machinery and the left Y axis represents the noise levels (dB) at SR, while the X-axis accounts for the frequency in Hz.

3. RESULTS AND DISCUSSION

The present section highlights the measurement processing step utilizing FFT analysis. It is to be noted that if no correlation was identified, the measurement point was excluded. Therefore, the following sources were identified as potential contributors:

- Transformers
- Cooling Units (Chillers)
- Pumps
- Air Cooler
- Ice Maker Outdoor Unit

3.1 Transformers

Two transformers were identified in the study area: Transformer 1 (R1), located 170 m from SR, and Transformer 2 (R20/R33), located 85 m from SR, both operating continuously. It was observed that both transformers correlate with the nighttime spectrum measured at SR, with Transformer 2 having a higher contribution due to its closer proximity and higher noise levels. Figure 3 and Figure 4 below illustrates the FFT analysis charts for both transformers.

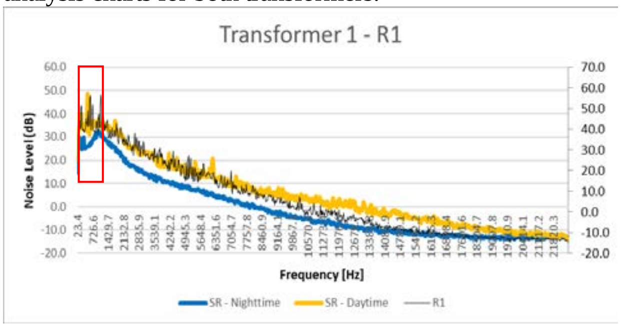

Figure 3. Transformer 1 (R1) FFT Chart.

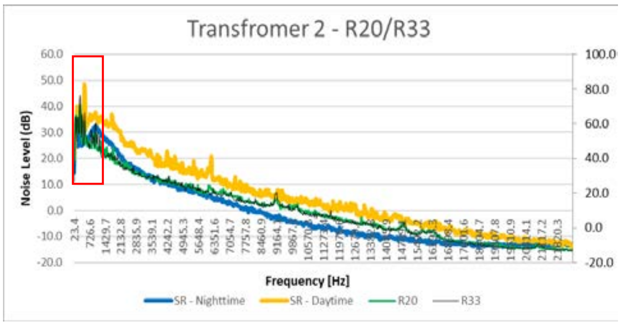

Figure 4. Transformer 2 (R20/R33) FFT Chart.

3.2 Cooling Units (Chillers)

Although five different Chillers were examined, only Cooling Unit 5 (R23), which has intermittent operations during daytime, showed significant correlation with the daytime noise spectrum observed at SR in the low and mid-frequency ranges, due to the following reasons:

a) It is the closest Chiller at 90 m distance from SR.

b) It is positioned on the rooftop of the Hypermarket, above the existing noise barrier.

c) It is oriented perpendicularly to SR.

The FFT analysis showed that in the low and mid-frequency ranges, e.g. 492 Hz, 750 Hz, 1000 Hz, and up to 7200 Hz, the Chiller's spectrum precisely with the peaks identified in the daytime spectrum at SR. However, the peak observed in the high-frequency range (around 15k Hz) in the Chiller's spectrum did not have an impact at SR, due to its rapid attenuation with distance compared to lower frequency. As a result, it was no longer detectable at SR. Figure 5 below depicts the FFT analysis chart for Cooling Unit 5.

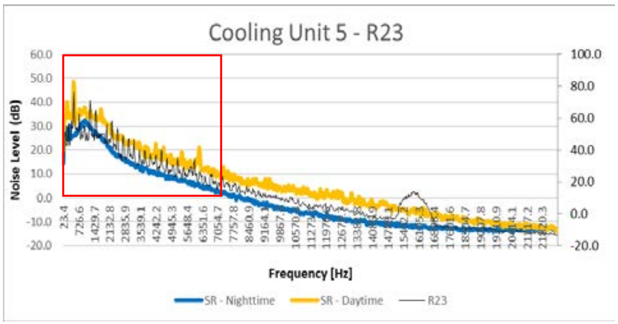

Figure 5. Cooling Unit 5 (R23) FFT Chart.

3.3 Pumps

Two measurements were conducted to analyze the spectrum of the Pumps, R30 and R37, which operate continuously during the day and night. The FFT analysis showed a weak correlation observed during nighttime only at 492 Hz. However, they are located 140 m from SR. Therefore, it was concluded that they are not a main contributor to the annoyance observed at SR. Figure 6 presents the FFT analysis chart for Pumps.

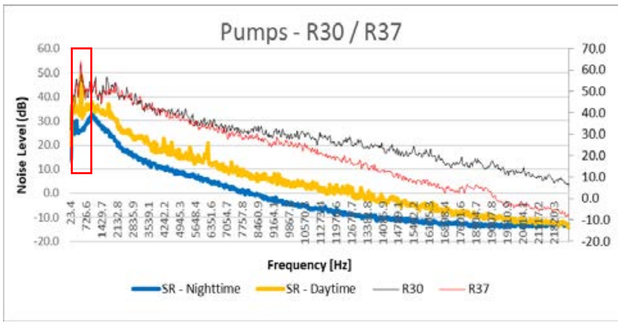

Figure 6. Pumps FFT Chart.

3.4 Air Cooler

Air Cooler, located 112 m from SR, was also evaluated. Two measurement were conducted around the unit, R22 and R34, to analyze its spectrum. Although the Air Cooler's noise was detectable at SR, both measurement indicated weak correlation during its intermittent operations in both daytime and nighttime. Therefore, it did not contribute to the reported annoyance, which can be linked to the characteristics of the noise source, as it lacked tonal or narrowband components. Figure 7 below depicts the FFT analysis chart for the Air Cooler.

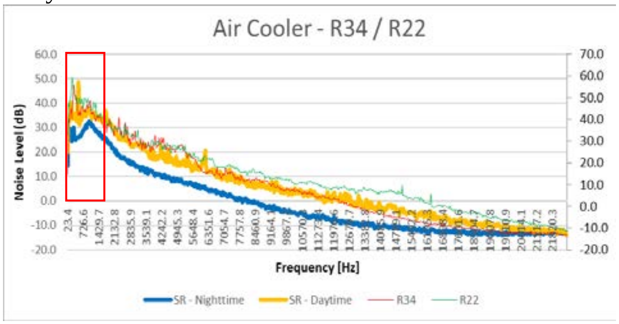

Figure 7. Air Cooler FFT Chart.

3.5 Ice Maker Outdoor Unit

The Ice Maker Outdoor Unit (R19) spectrum showed a weak correlation with the spectrum recorder at SR during nighttime. Despite being 85 m from SR, it was observed that its noise level at 1 m is not high enough to reach SR, especially that it is located behind the noise barrier. Therefore, it can be concluded that the correlation is due to another equipment which has similar characteristics, which in this case is Transformer 2. Figure 8 below depicts the FFT analysis chart for the Ice Maker Outdoor Unit.

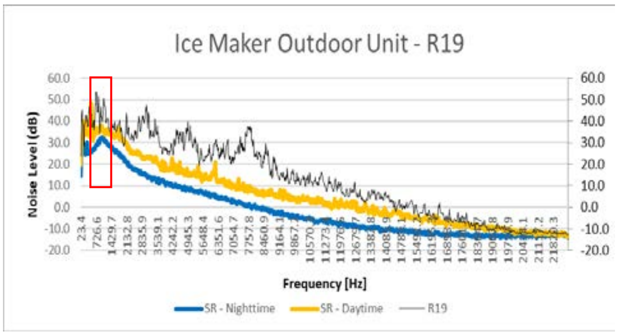

Figure 8. Ice Maker Outdoor Unit FFT Chart.

4. CONCLUSION

This study aimed to analyze the primary noise sources contributing to the disturbance reported by the residents of a dwelling located in front of a Hypermarket. A comprehensive noise measurement campaign was carried out to identify the most significant noise contributors operating within and on the rooftop of the Hypermarket utilizing FFT analysis. The results depicted that during daytime, the most significant contributor is Cooling Unit 5 (Chiller). This conclusion was based on the high correlation between its spectrum and the spectrum recorded at SR, its distance from SR, its high noise levels., and its position on the rooftop above the noise barrier, oriented perpendicularly to SR. However, its operation is intermittent and limited daytime.

During nighttime, it was observed that both Transformer 1 and Transformer 2, correlate with the measured spectrum at SR. Among them, Transformer 2 is more likely to be the primary contributor, due to its higher noise levels being significantly closer to the dwelling.

Other equipment, such as Ice Maker Outdoor Unit, Pumps, and Air Cooler, were also considered as potential contributors. However, the FFT analysis showed a weak correlation with SR. Additionally, site conditions, including their location and distance from SR, indicating that these source are either not detectable or had a negligible effect on the recorded noise levels at SR during both daytime and nighttime.

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