UNIVERSIDAD TÉCNICA DE MANABÍ
Fundada en 1952

RIEMAT
Revista de Investigaciones en Energía, Medio Ambiente y Tecnología:

Sounding Solutions: Mobile App-Based Noise Control in Artisan Workshops in Ecuador

Soluciones sonoras: Control del Ruido en Talleres Artesanales de Ecuador Mediante una Aplicación Móvil

Autores

Jorge Jimmy Ramírez Becerra [1]
https://orcid.org/0000-0001-7833-2804

Rolando Calero Mendoza [1*]
https://orcid.org/0000-0002-8931-9469

Gerardo Antonio Herrera Brunett [1]
https://orcid.org/0009-0009-8545-6704

[1] Facultad de Ciencias de la Ingeniería, Universidad Estatal Península de Santa Elena. Santa Elena, Ecuador.

* Autor para correspondencia.
rcalero@upse.edu.ec

Citacion sugerida: Ramírez, J., Calero, R., & Herrera, G. (2025). Sounding Solutions: Mobile App-Based Noise Control in Artisan Workshops in Ecuador. *Revista de Investigaciones en Energía, Medio Ambiente y Tecnología. RIEMAT, 10(1), pp. 14-22* https://doi.org/10.33936/riemat.v10i1.7311

Recibido: 18/09/2024
Aceptado: 22/11/2024
Publicado: 02/02/2025

Abstract

Mobile technologies have contributed to notable improvements in occupational health and general physical well-being by offering applications designed for disease prevention and care. This study aims to highlight the importance of preventive measures through the use of mobile applications to mitigate long-term hearing problems in industrial workshop operators exposed to high decibel levels. The study involved collecting data through structured surveys and conducting a comparative analysis of the effectiveness of mobile applications versus a standard sound level meter.

Selected industrial workshops in the city of La Libertad (Ecuador) were analyzed using an exploratory and correlational methodology with qualitative components. This methodology incorporated a digital sound level meter along with a free-access mobile application. The results revealed minimal discrepancies (less than X dB) in measurement outcomes between the mobile application and the benchmark sound level meter, indicating their high measurement congruence. Consequently, it can be concluded that the integration of these applications into daily routines could significantly enhance the systematic monitoring of occupational noise, serving as an effective tool to promote and protect occupational health.

Keywords: Occupational noise, mobile applications, artisan workshops, noise exposure,occupational health, preventive measures.

Resumen

Las tecnologías móviles han contribuido a mejorar notablemente la salud laboral y el bienestar físico general al ofrecer aplicaciones diseñadas para la prevención y el cuidado de enfermedades. Este estudio pretende destacar la importancia de las medidas preventivas mediante el uso de aplicaciones móviles para mitigar los problemas auditivos a largo plazo en operarios de talleres industriales expuestos a altos niveles de decibelios. El estudio consistió en recopilar datos mediante encuestas estructuradas y realizar un análisis comparativo de la eficacia de las aplicaciones móviles frente a un sonómetro estándar. Se analizaron talleres industriales seleccionados en la ciudad de La Libertad (Ecuador) utilizando una metodología exploratoria y correlacional con componentes cualitativos. Esta metodología incorporó un sonómetro digital junto con una aplicación móvil de libre acceso. Los resultados revelaron discrepancias mínimas (menores a X dB) en los resultados de medición entre la aplicación móvil y el sonómetro de referencia, indicando su alta congruencia de medición. En consecuencia, se puede concluir que la integración de estas aplicaciones en las rutinas diarias podría mejorar significativamente la vigilancia sistemática del ruido ocupacional, sirviendo como una herramienta eficaz para promover y proteger la salud ocupacional.

Palabras clave: Ruido ocupacional, aplicaciones móviles, talleres artesanales, exposición al ruido, salud laboral, medidas preventivas

1. Introduction

The effect of exposure to high levels of noise caused by industrial activities, such as construction and the use of machinery, generates sounds with varying frequency levels that lead to a decrease in auditory capacity (Martínez et al., 2012; Enshassi et al., 2014; Aamir, M. P., et al., 2018). The constant exposure to these noise levels is associated with increased cortisol levels, resulting in reduced immunity and the emergence of health problems such as elevated blood pressure and nervous disorders, including anxiety, insomnia, and chronic fatigue (Gronski, 2017). Additionally, noise has been speculated to be a potential cause of heart disease and stomach ulcers (Curran et al., 2013; Escobar & Divisón, 2016).

Estimates suggest that approximately 22 million workers are exposed to hazardous noise levels annually. Beyond impacting workers' quality of life, occupational hearing loss carries a significant economic cost for society (Roberts et al., 2016).

The health consequences of workplace noise exposure can be severe (Kesuma & Nasution, 2019). In 2022, Germany recorded 15,449 suspected cases of occupational diseases caused by noise exposure. In the United States, noise-induced hearing loss affected 39.1% of men and 18.3% of women exposed to occupational noise. The incidence of noise-induced health issues varies significantly across different occupational sectors. In Singapore, noise-induced deafness was the leading occupational illness in 2023, with 804 cases documented. The metal industry reported the highest number of workers under medical observation for noise exposure, totaling 24,206 individuals. In Germany, the construction sector identified 4,010 potential cases of noise-induced hearing loss in 2022. Nationally, 15,449 suspected instances of noise-induced occupational disease were recorded that year. These statistics highlight the critical need for preventive strategies in high-noise environments, especially within industries such as metallurgy and construction (Statista, 2024).

The lack of control and absence of internal regulations in workplace environments contribute to preventable accident risks and errors in job performance (Khajenasiri et al., 2016). Communication is hampered due to prolonged exposure in settings such as construction, foundries, manufacturing, and textiles (Echevarría, 2019).

In La Libertad city, Santa Elena province (Ecuador), an inspection of industrial and artisanal workshops has been conducted, where noise generated by machinery has raised concerns due to its potential implications on work efficiency and occupational health of operators. This chronic noise exposure can result in symptoms of hearing loss, imbalance, disorientation, and concentration difficulties in the long run.

Within this context, the current work focused on analyzing essential aspects that both small and large workshops must consider to reduce noise effects. A proposed solution lies in the implementation of daily individual control through mobile applications, fostering habits and alerting about risks through a labor risk traffic light system. Several of these applications are available on mobile devices, facilitating comparison with digital sound level measurements. This enables potential control over noise levels and exposure duration, allowing for the regulation of work areas in industrial workshops. This innovation is essential to strengthen job skills, improve quality, and reduce errors, in line with individual resilience capacities (Prado Cruz, 2018).

The ubiquity of smartphones and the advanced level of sound measurement applications present an exceptional opportunity to revolutionize current data collection and noise monitoring practices. Through mass collaboration techniques, workers worldwide can use their mobile devices to gather and share information on noise exposure in their workplaces (Jacobs et al., 2020).

Table 1

Comparative Analysis of Noise Measurement Apps (1,2)

App	Measurement Accuracy	Detection Capability	Compliance with Standards	User Interface Quality	Additional Features
NIOSH Sound Level Meter	High (±2 dB)	High: Measures SPL, A, C, Z weightings	Complies with ANSI S1.4-1983, IEC 61672-1	Very good: Clear, educational interface	Data logging, graphs, CSV export
Sound Meter (Decibel)	Moderate (±3-4 dB)	Moderate: Measures SPL, environmental noise	Does not explicitly comply with standards	Good: Simple and user-friendly	Noise alerts, real-time graphs
Sound Meter PRO	High (depending on calibration)	High: Allows microphone calibration	Does not explicitly comply with standards	Very good: Detailed, customizable	Custom calibration, data export
Decibel X	Moderate-High (±2-3 dB)	High: A and C weightings, visual indicators	Does not explicitly comply with standards	Very good: Intuitive, visual indicators	History, data export, graphs
SPLnFFT Noise Meter	High (±1-2 dB, after calibration)	Very High: FFT analysis, multiple weightings	Complies with advanced precision standards	Excellent: Comprehensive, visual analysis	FFT analysis, CSV export, multiple profiles
dB Meter	Moderate (±3-4 dB)	Moderate: Measures SPL, real-time noise levels	Does not explicitly comply with standards	Good: Clear, easy-to-use interface	Data saving, night mode
Sound Level Analyzer Lite	High (±2 dB after calibration)	High: A, C, Z weightings, continuous mode	Complies with some precision standards	Good: Detailed, good visualization	Data export, custom calibration

Source: (1) Huyan, J., Ramkissoon, C., Laka, M., & Gaskin, S. (2023, November 14). Assessing the Usefulness of Mobile Apps for Noise Management in Occupational Health and Safety: Quantitative Measurement and Expert Elicitation Study. http://doi.org/10.2196/46846
(2) Kardous, C. A., Shaw, P. B., & Murphy, W. J. (2016, April 1). Evaluation of smartphone sound measurement applications using external microphones—A follow-up study. Journal of the Acoustical Society of AmericaAcoustical.

It's really interesting that some mobile noise measurement apps mentioned earlier offer high accuracy and compliance with regulatory standards, making them reliable tools for workplace noise monitoring. While other apps are suitable for general environmental use, professional environments benefit from apps with advanced features such as custom calibration and data export, ensuring effective auditory protection.

2. Materials and methods

The study encompassed a comprehensive and methodical exploration of existing literature, including qualitative analysis through perception surveys. These surveys aimed to gauge the respondents' level of awareness regarding the impact of noise on both their work performance and health. Moreover, the surveys explored the necessity of adopting protective measures. Additionally, a comparative assessment was conducted, correlating measurements obtained from a certified digital sound level meter, the SESVA SC310, with data collected using the NIOSH mobile sound level meter application for smartphones.

To gather insights, a written survey was distributed among 30 randomly selected workers out of a total of 150, representing diverse artisan workshops. The questionnaire targeted machine tool operators in the industrial workshops of La Libertad city, located in the province of Santa Elena, Ecuador. These artisans, skilled in handling various machinery, provided affirmative or negative responses to questions that illuminated their daily work experiences. The goal was to understand the influence of occupational noise on ear-related issues commonly reported among machine tool operators. Concurrently, a comparative analysis of select mobile applications was performed, assessing their accuracy against measurements captured by a traditional sound level meter.

The necessary sample size was determined based on various factors, including the level of confidence, significance, data variability, and the effect size expected to be detected.

The formula used to calculate the required sample size was for finite populations, applicable when the population is relatively small compared to the desired sample size. The formula is as follows:

$$n = \frac{Nz^2 p(1-p)}{(N-1)e^2 + z^2 p(1-p)} \quad (1)$$

Where:

- **n** is the required sample size.
- **N** is the total population size (150 in this work).
- **z** is the value corresponding to the desired level of confidence (for example, 1.96 for a 95% confidence level).
- **p** is the estimation of the proportion in the population that exhibits a certain characteristic or behavior (if there's no prior estimation, you can assume p=0.5 for a more conservative sample size estimation).
- **e** is the maximum permissible error in the estimation (half of the width of the confidence interval).

2.1. Sampling locations

2.1.1 Location A: Ice Factory.

Interviews were undertaken with operators, and a sampling methodology was employed to assess the efficacy of mobile applications. This assessment encompassed the quantification of workplace noise exposure levels and duration, coupled with the identification of specific machinery and instruments contributing to the highest occurrences of occupational noise. The sampling sessions extended over approximately two hours, targeting moments marked by peak levels of occupational noise for collection.

2.1.2 Location B: Ice factory.

The sample gathered, both through the sound level meter and the mobile application, pertains to the machinery and instruments characterized by the most significant occurrences of occupational noise within the operators' workspaces. These collection sessions spanned a duration of approximately two hours, conducted during peak noise pollution hours.

2.1.3 Site C: Fish Processing Plant

The investigation into occupational noise within this facility was conducted during the peak working hours of 10 a.m. to 12 p.m., a period of heightened activity. Measurements were captured using both a standardized sound level meter and the NIOSH application via smartphone.

2.1.4 Site D: Industrial Mechanic Workshop

Sound samples were acquired within an industrial factory situated in the city of La Libertad, within the province of Santa Elena, Ecuador. These samples pertained to Pinacho lathe instruments mod L-1/260/660/3000, exhibiting a noise level of 71.9 dB, and a grinder with an average noise reading of 71.9 dB.

2.1.5 Site F: Mechanical Industrial Workshop

Sampling occurred between 2:00 and 4:00 p.m., spanning a duration of approximately two hours during the machinery's peak operation. The analysis was conducted on individual instruments: TOR D500 lathe with an average noise level of 75.2 dB, Lagun 8 275 milling machine with an average noise level of 67.2 dB, Miller Dialarc 250 welder with an average noise level of 75.8 dB, electric drill producing 74.6 dB noise, grinder with an average noise level of 77.2 dB, Dewalt grinder yielding a noise index ranging between 75.8 and 85.7 dB, and finally, a grinder exhibiting a minimum average noise level of 72.6 dB.

2.1.6 Site E: Furniture Company

Also situated in La Libertad city, this furniture company's noise profile was assessed by isolating measurements for each individual machine. Notably, a vertical cutter recorded an average noise level of 77.8 dB.

2.2 Statistical analysis

The NIOSH application was selected as the benchmark for mobile applications. This application is designed for the prevention of hearing loss and is compatible with both iOS and Android platforms.

Subsequently, data encompassing the total duration, average noise level (LAeq for NIOSH measurements), Lmax, projected 2-hour time-weighted average (2 h TWA), and projected percentage dose were meticulously recorded in Microsoft Excel to facilitate thorough analysis.

To offer comprehensive insights, various statistical parameters were computed. These included the mean, standard deviation (SD), and the percentage of measurements surpassing the level of detection (LOD) for the exposure time as measured by the dosimeter. Furthermore, LAeq results were averaged per location, bridging the gap between data acquired through the dosimeter and the smartphone application.

Calculations were extended to encompass LAeq, LAmax, and the TWA projected on both the smartphone and the dosimeter, ensuring a comprehensive and accurate assessment of noise exposure.

3. Results and Discussion

3.1. Survey results

The outcomes derived from the surveys reveal a discernible impact of noise on work performance and concentration. A significant portion, constituting 58%, reported experiencing some degree of disruption in their activities due to noise, while 41.67% indicated otherwise.

Regarding the inquiry concerning the prevalence of auditory discomfort stemming from continuous machinery exposure, a notable 66% of workers affirmed experiencing such discomfort, whereas 34% reported no associated discomfort. In essence, a considerable proportion of the workforce is exposed to a potential risk of permanent or transient hearing impairment.

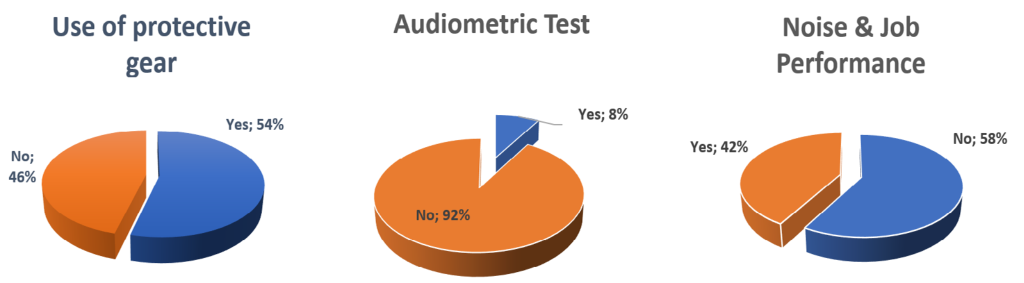
When queried about proactive measures taken for auditory health, a mere 8% indicated undergoing regular audiometric examinations, leaving 92% without such precautions.

Concerning the utilization of protective equipment, 54% of respondents confirmed their adherence to protective equipment usage, while 46% did not. This finding underscores that a substantial proportion of operators are susceptible to hearing impairments, underscoring the need for enhanced protective measures.

The surveys were designed to gather qualitative information on participants' perceptions and experiences, offering insights into factors that may not be captured by direct measurements alone. Concurrently, objective measurements were performed to collect quantifiable data essential for the accuracy and rigor of the analysis. By integrating both approaches, we aimed to cross-validate the results: subjective data from the surveys were used to support or contrast the objective measurements, providing a comprehensive understanding of the variables under study. This mixed-method approach ensures a thorough assessment, accounting for both perceptual and measurable aspects of the investigated environment.

Graph 1

Results of surveys conducted on workers exposed to occupational noise levels.



Source: Authors

3.2 Measurement studies

In pursuit of the measurement study's objectives, a comparative analysis was conducted between the NIOSH smartphone mobile application and a bona fide standardized sound level meter.

The field study encompassed six industrial and artisanal workshops, where noise emissions from various equipment, including lathes, milling machines, welding machines, drills, grinders, and additional grinders, were measured using both an Apple iPhone 11 smartphone and a SESVA SC310 sound level meter, which served as the benchmark measurement instrument.

Mobile applications are designed to gauge sound levels, functioning as tools for quantifying acoustic intensities within workplaces and delivering pertinent parameters of noise exposure. This analytical framework aids in the mitigation of hearing loss induced by occupational noise (Williams et al., 2017).

Importantly, it must be noted that professional sound level meters undergo rigorous acoustic and electrical assessments to align with national and international standards. As of the present, no smartphone or smartphone application has met the requisite criteria stipulated by the corresponding IEC or ANSI standards.

By using reliable instruments calibrated according to international standards, we aimed to collect data that could serve as a baseline for comparing subjective perceptions with actual recorded levels. The objective data from these measurements is important for making reliable conclusions and allowing the study to be replicated accurately.

OSHA studies have established the permissible exposure limits (PEL) for noise at 90 dB(A) during an 8-hour Time-Weighted Average (TWA), adopting a 5-dB exchange rate as the basis. Occupational standards meticulously outline the maximum permissible percentage of daily noise dose. According to these guidelines, an individual subjected to 90 dB(A), adhering to the OSHA standard, will reach 100% of their daily noise dose over an 8-hour work shift. The computation of noise dose is contingent upon both the intensity of exposure and the duration of exposure. It is noteworthy that for each incremental 3-dB elevation in averaged noise exposure, the permissible duration of exposure is halved accordingly.

Table 2

Permitted Noise Exposure Level

Time Weighted Average (TWA) dB(A)	Time to reach 100% of the daily noise dose (h)
85	8
88	4
91	2
94	1
97	0,5
100	0,25

Source: Authors

With an external microphone. Their objective was to ascertain the conformity of this system to the Type 2 requirements outlined in both IEC 61672 and ANSI S1.4 for Sound In accordance with Kardous and Shaw (2016), their study demonstrated that applications utilized in conjunction with calibrated external microphones exhibit a remarkable similarity to type 1 reference sound level meters, boasting an accuracy within ±1 dB(A).

Professional sound level meters (SLMs) are mandated to adhere to stringent national and international standards, including the specifications outlined in the American National Standards Institute (ANSI) S1.4-2014 (R2007) for sound level meters and the International Electrotechnical Commission (IEC) standard 61672. The convergence of ANSI and IEC standards was realized in 2014. These benchmarks institute rigorous acoustic, electrical, and environmental tests, incorporating specific tolerance margins and measurement uncertainties denoted in decibels across a comprehensive frequency spectrum, typically spanning 10 Hz to 20 kHz. The parameters encompassed by these assessments encompass level linearity, directionality, temporal and frequency-weighting responses, tone bursts, mitigation of radio frequency interference, and considerations of atmospheric and environmental conditions. Furthermore, these protocols stipulate that assessments encompass the entire instrument ensemble, encompassing both microphone and preamplifier.

Celestina et al. (2018) subjected the NIOSH application to a comprehensive evaluation as a component of a system comprising an iPhone equipped Level Meters, Part 3. The investigation, executed through periodic testing, culminated in the affirmation that the results achieved met the standards outlined for the standardized equipment.

Throughout the measurements conducted across varied semi-industrial workshops, it was evident that the SESVA sound level meter and the mobile application yielded marginal disparities in terms of noise measurements. It is noteworthy that the recorded maximum levels fluctuated within the range of 75 to 92 dB, a concerning amplitude that alludes to the potential for hearing impairment due to heightened exposure during peak hours. Moreover, the lack of adherence to protective measures by operators exacerbates this predicament.

The disparities between the NIOSH application and the SESVA sound level meter were found to be nominal, indicating congruence in their measurements. This suggests that the consistent utilization of the mobile application, facilitated by its user-friendly interface, could enhance individual awareness and conscientiousness regarding the implementation of protective equipment among operators (Table 3).

Table 3

Comparative results of the use of the sound level meter and the NIOSH application.

	N°	SONOMETRO (SESVA SC310)	DESV	App NIOSH /IPHONE 11 Laeq (dB)	TWA (dB)	RUN TIME (MIN)
LOCATION A	6	91,8	1,17	86,0	3,69	120
LOCATION: B	9	89	2,58	89,5	5,17	120
LOCATION: C	12	88,625	3,7	84,775	5,4	120
LOCATION:D	6	79,22	2,38	75,22	3,62	120
LOCATION: E	6	75,4	1,3	74,8	3,1	120
LOCATION: F	4	79,5	5,7	79,4	6,7	120

Source: Authors

It is imperative to acknowledge that while smartphone applications offer utility, the precision of measurements hinges on the employment of standardized measurement instruments. This observation, however, should not diminish the significance of proactive and preemptive adoption of alternatives. These alternatives hold the potential to assess the auditory well-being of factory operators, who encounter daily exposures.

4. Conclusions

Our findings indicate that disparities between the mobile application and the SESVA sound level meter are negligible, with each measurement showing a maximum difference of no more than 5 dB. This highlights the importance of operators consistently using such tools, which, in turn, increases the potential for effective occupational noise control, particularly in environments where auditory well-being is critical.

Comparative studies of mobile noise measurement apps, supported by findings from the bibliography, reveal a variety of options suited for different needs, ranging from casual environmental monitoring to professional workplace compliance. Apps such as NIOSH Sound Level Meter and SPLnFFT Noise Meter are notable for their high accuracy, advanced features, and compliance with international standards, making them reliable for occupational noise assessments. In contrast, simpler apps like Sound Meter (Decibel) and dB Meter are suitable for personal use or basic noise monitoring but lack the precision and regulatory compliance necessary for more demanding environments. Ultimately, the choice of app depends on its intended application, with more advanced tools being essential for settings that require strict auditory safety measures.

5. References

Gronski, M., & Neville, M. (2017). Vestibular impairment, vestibular rehabilitation, and occupational performance. AJOT: *American Journal of Occupational Therapy, 71(S2)*, 7112410055p1-7112410055p1. Doi: 10.5014/ajot.2017.716S09

Jacobs, N., Roberts, B., Reamer, H., Mathis, C., Gaffney, S., & Neitzel, R. (2020). Noise exposures in different community settings measured by traditional dosimeter and smartphone app. *Applied Acoustics, 167, 107408*. https://doi.org/10.1016/j.apacoust.2020.107408

Prado Cruz, D. D. (2018). Desarrollo de un aplicativo móvil para fortalecer la identificación, evaluación y control de riesgos en procesos de mantenimiento de celdas de flotación en industria minera. https://hdl.handle.net/20.500.12867/1620

Kardous, C. A., & Shaw, P. B. (2014). Evaluation of smartphone sound measurement applications. *The Journal of the Acoustical Society of America, 135(4)*, EL186-EL192. https://doi.org/10.1121/1.4865269

Echevarria Jesus, P., & Pérez Torres, E. W. (2019). Propuesta de diseño de una app móvil para alertar la ocurrencia de accidentes de trabajo en una empresa constructora en el Perú. https://hdl.handle.net/20.500.12867/3281

Enshassi, A., Kochendoerfer, B., & Rizq, E. (2014). Evaluación de los impactos medioambientales de los proyectos de construcción. *Revista ingeniería de construcción, 29(3), 234-254.* http://dx.doi.org/10.4067/S0718-50732014000300002

Escobar, C., & Divisón, J. A. (2016). Ruido y enfermedad cardiovascular. *SEMERGEN, Soc. Esp. Med. Rural Gen.(Ed. Impr.), e65-e66*. https://pesquisa.bvsalud.org/portal/resource/pt/ibc-155034

Kardous, C. A., & Shaw, P. B. (2016). Evaluation of smartphone sound measurement applications (apps) using external microphones—A follow-up study. *The Journal of the acoustical society of America, 140(4), EL327-EL333*. https://doi.org/10.1121/1.4964639

Celestina, M., Hrovat, J., & Kardous, C. A. (2018). Smartphone-based sound level measurement apps: Evaluation of compliance with international sound level meter standards. *Applied Acoustics, 139, 119-128*. https://doi.org/10.1016/j.apacoust.2018.04.011

Roberts, B., Kardous, C., & Neitzel, R. (2016). Improving the accuracy of smart devices to measure noise exposure. *Journal of occupational and environmental hygiene, 13(11), 840-846*. https://doi.org/10.1080/15459624.2016.1183014

Williams, W., Zhou, D., Stewart, G., & Knott, P. (2017). Facilitating occupational noise management: The use of a smartphone app as a noise exposure, risk management tool. https://openurl.ebsco.com/EPDB%3Agcd%3A3%3A15176275/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A124923072&crl=c&link_origin=scholar.google.es

Martínez, M. G., García, J. J. J., Ceballos, L. Y., Valencia, A. M., Zapata, M. A. V., & Trespalacios, E. M. V. (2012). Ruido industrial: efectos en la salud de los trabajadores expuestos. Revista CES Salud Pública, 3(2), 174-183. https://dialnet.unirioja.es/servlet/articulo?codigo=4163349

Muhammad Aamir, P., Danish Ail, M., Aqeel Ahmed, B., Qadir, B. J.,(2018) Impact of Noise Pollution on Human Health at Industrial SITE Area Hyderabad. *Indian Journal of Science and Technology.* DOI: 10.17485/ijst/2018/v11i31/130436

Curran, J. H., Ward, H. D., Shum, M., & Davies, H. W. (2013). Reducing cardiovascular health impacts from traffic-related noise and air pollution: intervention strategies. *Environmental Health Review.* https://doi.org/10.5864/d2013-011

Khajenasiri, F., Zamanian, A., & Zamanian, Z. (2016). The Effect of Exposure to High Noise Levels on the Performance and Rate of Error in Manual Activities. *Electronic physician*. doi: 10.19082/2088

Kesuma, E., & Nasution, M. E. S. (2019). Risk Factors Analysis Of Hearing Disorders Due To Noise On Machinery Workers At Universal Steel Factory. *Buletin Farmatera*. https://doi.org/10.30596/bf.v4i2.2989

Huyan, J., Ramkissoon, C., Laka, M., & Gaskin, S. (2023, November 14). Assessing the Usefulness of Mobile Apps for Noise Management in Occupational Health and Safety: Quantitative Measurement and Expert Elicitation Study. https://doi.org/10.2196/46846