CHEMICAL ENGINEERING TRANSACTIONS
VOL. 87, 2021
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Laura Piazza, Mauro Moresi, Francesco Donsì

ISBN 978-88-95608-85-3; **ISSN** 2283-9216
DOI: 10.3303/CET2187068

Ambient and Personal Noise Exposure Assessment in a Pasta Factory

Biagio Bianchi[a], Antonia Tamborrino[a,*], Ubaldo Ayr[b], Antonio Berardi[d], Pasquale Catalano[c]

[a]Dep.of Agricultural and Environmental Science, University of Bari Aldo Moro, Via Amendola 165/A – 70126 Bari, Italy
[b]Department of Civil Engineering and Architecture Sciences, Polytechnic of Bari, via Orabona 4, 70125 Bari, Italy
[c]Department of Agriculture, Environment and Food, University of Molise, Via De Sanctis. n.c. – 86100 Campobasso, Italy
[d]Dip. di Science Agrarie, Alimenti, Risorse Naturali e Ingegneria (DAFNE), Università degli Studi di Foggia, Italy
antonia.tamborrino@uniba.it

Noise pollution is one of the most important risk factors in industrial settings. This study is assessing ambient and personal noise exposure among workers of a pasta factory. Two kinds of measurements were taken; at a fixed work point in three areas and personal ones for different employees; for 8h at different times. Results for the measurements carried out at fixed sample points show that exposure times of ≤ 8h are the same. The highest noise levels are in the press and packaging areas. Worker's activity is well planned as their movements avoid staying for a long time in areas where their continuous noise exposure can exceed the most critical values. Dosimeter data can be a source of concern for the workers' health and therefore for their employers. Operators are engaged to work very close to machines; so they are subjected to levels of noise exposure different from that measured in fixed sample points. This study has further confirmed that the risk evaluation is not an exact science; as it doesn't consist only of technical and mechanical factors, but needs also to consider the factors connected to workers' interaction with the workplace.
Keywords: Phonometer, dosimeter measures, noise risk assessment, safety procedures.

1. Introduction

Noise exposure is one of the most present occupational hazards. Hearing conservation program legislations were designed to lower noise-induced hearing loss's risk (Angulo et al.,2019). In Italy, the National Institute for Insurance against Accidents at Work (INAIL) reports, in 2013-2017, an average of 1.268,0 reported cases of occupational illnesses in the food industry, of which 4% due to hypoacusis. In the food production and processing industry, electrical machines are the most used (Ayr et al., 2015; Tamborrino et al., 2019; Catalano et al., 2020) causing the main sources of noise. However, they are often assembled in complex workstations, an occurring sum of sound or resonance levels. Furthermore, workers often move to different positions, depending on their operations. In other cases, noise sources can be very different, for example, live animals (Bianchi, 2015; Bianchi, 2017; Giametta et al., 2017) particular loading and unloading operations, vibrating structures, or machines (Catalano et al., 2013, Tamborrino et al., 2014 and Leone et al., 2015). Therefore, it is important to carry out specific noise assessments, to appropriately study the distribution of tasks during the working day, and to adopt suitable individual protection devices (Kozlowski et al., 2019). Pasta factories are highly mechanized, particularly at the stages of production (Huang et al., 2019; Caciari et al., 2013). The machinery used is more efficient (Perone et al., 2017) but can create dust and noise pollution (Vijayraghavan et al., 1999; Passchier-Vermeeret et al.,2000). The development of mechanized systems for the production cycle leads to changes in the layout of the workspace, in the types of work, carried out by the workforce, and the interaction between man and machine. Consequently, the methodologies and the tools used to evaluate risks in the workplace also change, depending on the health problems and accidents during the production process, and also on the limits imposed by the technical regulations – which often translate into legal obligations (Becklake et al., 1996; Stansfeld et al., 2003). Noise pollution is caused by the highly mechanized plants installed in the last few years, and risk assessment is correlated not only to the kind of machinery used

Paper Received: 17 September 2020; Revised: 3 March 2021; Accepted: 9 April 2021
Please cite this article as: Bianchi B., Tamborrino A., Ayr U., Berardi A., Catalano P., 2021, Ambient and Personal Noise Exposure Assessment in a Pasta Factory, Chemical Engineering Transactions, 87, 403-408 DOI:10.3303/CET2187068

but also to other factors like the degree of maintenance, the positioning of machinery in the buildings, the structure of the buildings, etc. (Orga et al., 2018; Nyarubeli et al., 2019). Such problems are often experienced in the agricultural and agro-industrial sectors, particularly during the sorting and packing phases (Kozlowski et al., 2019; Merseburger et al., 1997). The goal of this study is to evaluate risks from noise in a pasta factory in Bari (Italy). The research has been carried out considering the limits set by the current legislation and by the technical regulations and by the measuring instruments, which are permitted to carry out the risk assessment.

2. Materials and method

The experimental trials were carried out in a pasta factory in Corato (Bari - Italy) which produces short and long pasta, nests, and special pasta. Production is concentrated on four lines located near the outside walls of the building (Figure 1): a 35 q/h short pasta line and a 22 q/h short pasta line; a 35 q/h long pasta line and a 20 q/h long pasta line (Figure 1). The other lines have a much lower work capacity, do not operate continuously, and are located further back in the building (Figure 1).

The manufacturing department of the factory can be divided into four areas:

- press area, including the starting of the lines, before the driers (Figure 1);
- driers area, including the driers and the pasta elevators (Figure 1);
- packaging area, including the packing lines, following the pasta elevators (Figure 1);
- storage area consisting of packaging store and storage products areas (Figure 1).

Production takes place in a single working area (Figure 1) where the pasta is prepared and extruded, dried, and packaged. The workforce (n. 80 workers) is concentrated in the press area and the storage/packaging area, as the drying phase is fully automated and requires the presence of workers only occasionally, to carry out checks.

Evaluation of the risk from noise exposure was carried out following the UNI EN ISO 9612: 2011, which have been transposed in the Italian law: UNI 9432: 2011 and Law Decree No. 81/08. According to the above standards, we carried out fixed noise and personal noise readings. The first readings were carried out by integrating sound level meters, Brüel & Kjær Sound Level Meter - Type 2250, according to the following standards: ANSI S1.4: Class/Type 1. Concerning the personal noise readings, we used 3M™ Edge™ 5 Personal Noise Dosimeter with the docking station, EG5-D, corresponding to the following standards: ANSI S1.25.

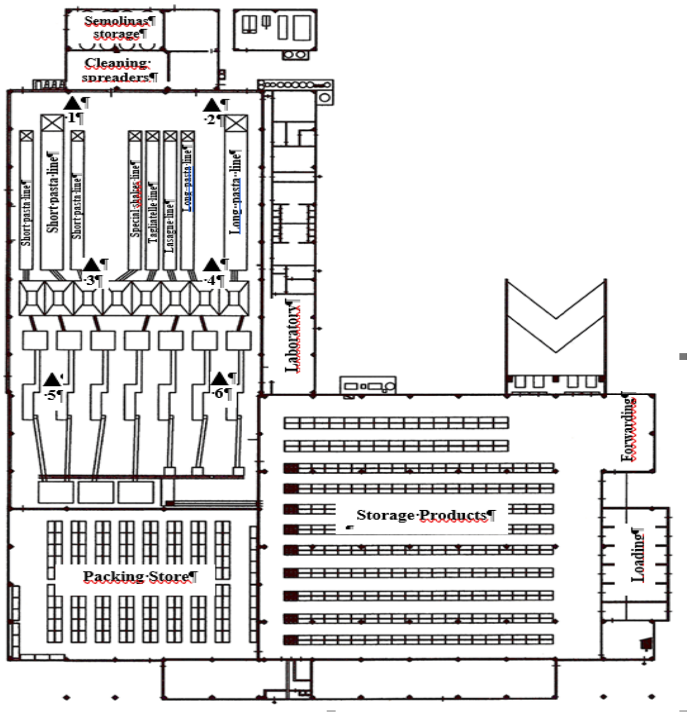

Figure 1: Schematic plan of the pasta factory; the symbols (⁂) indicate the noise fixed sample points. The image is not drawn to scale the second panel

To evaluate the risks of noise exposure, the production cycle and its layout were examined. Then the critical areas for these risk factors were identified, based on noise generated and the movements of the factory personnel. For this reason, the noise measuring equipment was placed in n. 6 representative positions:

1. press area for the short pasta line (sample point 1 in Figure 1);
2. press area for the long pasta line (sample point 2 in Figure 1);
3. the area between the dryers and pasta elevators for the short pasta line (sample point 3 in Figure 1);
4. area between the dryers and the pasta elevators for the long pasta line (sample point 4 in Figure 1);
5. short pasta packaging area (sample point 5 in Figure 1);
6. long pasta packaging area (sample point 6 in Figure 1).

The storage area is not affected by noise pollution, therefore no measuring points have been placed. Tests have been carried out for short exposure times and LEX,8h is always below 60 dB(A).
The Continuous Equivalent Level (Leq) to reduce the effect of phonometric fluctuations has been determined. This represents the level of a hypothetical constant noise, with the same duration and equivalent energy level, as the measured variable noise; it is the average total noise. The environmental noise measurements were weighted according to Curve A, which is closest to the sensitivity of the human ear to the different frequencies, while impulsive noise measurements were weighted according to Curve C.
According to international regulations ISO 1999: 2013, partially acknowledged by Italian law, the daily noise exposure level is expressed by the formula:

$$L_{EX,8h} = L_{Aeq,T_e} + 10\log\frac{T_e}{T_0} \quad \text{dB(A)} \qquad (1)$$

where: $L_{Aeq,Te}$ is the A-weighted equivalent continuous sound pressure level for Te:

$$L_{Aeq,T_e} = 10\log\left[\frac{1}{T_e}\int_0^{T_e}\left(\frac{p_A(t)}{p_0}\right)^2 dt\right] \quad \text{dB(A)} \qquad (1)$$

Te = the time at which the equivalent level is determined, including the daily share of over-time work; T_0 = the reference duration (T_0 = 8 h=28800 s);
p_o = 20 μPa;
p_A = instant acoustic pressure weighted in Scale A.

The average daily exposure level per task was calculated based on the levels obtained for each workplace using the following ratio:

$$L_{EX},8\square = 10\,log\left[\frac{1}{T_0}\sum_{i=1}^{n} T_{e-i}10^{0.1L_{EX,Te-i}}\right] L_{EX},8\square = 10\,log\left[\frac{1}{T_0}\sum_{i=1}^{n} T_{e-i}10^{0.1L_{EX,Te-i}}\right] \quad \text{dB(A)} \qquad (2)$$

where T_{e-i} is the A-weighted equivalent continuous sound pressure level for i-th noise exposure time T_e.
Before and after each series of measurements, the instruments were calibrated using a calibrator Quest mod QC 10/20, corresponding to the following standards, according to UNI EN ISO 9612: 2011:ANSI Standard for Sound Calibrators S1.40-1984; and IEC 942-1988 for Sound Calibrators.
A phonometer was installed in each workplace: for 8 hours and for shorter periods, which results represent the working day: 120 min, 47 min. All phonometers were adjusted before noise levels were measured.
To take further personal noise measurements, dosimeter microphones were placed 0.05 m from the shoulder and 0.6 m from the entrance to the external auditory channel of each operator; the cables and microphone were attached to the body of the person so they did not suffer any bumps. The dosimeters were worn by n. 4 machine operators, n. 2 packaging operators, and n. 2 electricians. For these workers, the average daily exposure level was also calculated, using (2) with fixed noise readings and T_e corresponding to real exposure times in the areas of each operator, according to Table 1.

Table 1: The time corresponding to real exposure times for the workers that dressed the dosimeters

Operator	Short pasta Press Area	Long pasta Press Area	Drying Area (initial part)	Drying Area (final part)	Short pasta Packaging Area	Long pasta Packaging Area	Storage Area
Machine operator 1	3 h	3 h	2 h	/	/	/	/
Machine operator 2	4 h	2 h	2 h	/	/	/	/
Machine operator 3	2 h	4 h	2 h	/	/	/	/
Machine operator 4	/	/	/	2 h	4 h	/	2 h
Electrician 1	2.5 h	2.5 h	3 h	/	/	/	/
Electrician 2	/	/	/	/	3 h	3 h	2 h
Packaging operator 1	/	/	/	/	3 h	5 h	/

During the tests it also was measured the peak noise level of exposure:

$$L_{p,peak} = 10\log\left(\frac{p_{peak}}{p_0}\right)^2 = 20\log\frac{p_{peak}}{p_{ref}} \qquad \text{dB(C)} \tag{3}$$

where: p_{peak} = instant acoustic pressure weighted in Scale C and p_0 = reference acoustic pressure: 20 µPa. All the tests were repeated 5 times, in different production days. Numerical processing of the data was carried out using periodically up-dated Quest software, mod. QuestSuite professional, rev. 1.70 and QuestSuite professional II. Statistical analysis of the data was based on the calculation of the mean and of the standard deviation, according to the nature of the single variables; the differences between the means were compared by using Student's t-test. The differences were considered significant when the p-values were lower than 0.05.

3. Results and discussion

The Italian law (Law Decree No. 81/08) and Directive 2003/10/EC set the following noise limits.

- exposure limit values: $L_{EX,8h}$ = 87 dB(A), $L_{EXp,peak}$ = 200 Pa (140 dB (C) in relation to 20 µPa respectively;
- upper exposure action values: $L_{EX,8h}$ = 85 dB(A), $L_{EXp,peak}$ = 140 Pa(137 dB(C) in relation to 20 µPa respectively;
- lower exposure action values: $L_{EX,8h}$ = 80 dB(A), $L_{EXp,peak}$ =112 Pa (135 dB(C) in relation to 20 µPa) respectively.

Figure 2 resume the measurements at the fixed sample points. The Upper $L_{EX,8h}$ value (85 dB(A)) is exceeded at the beginning of the short pasta line, in the press area, for the 8h and 2h measurings time, while for *Te* 47 min the $L_{EX,Te}$ is between the Upper and Lower $L_{EX,8h}$ values (85 and 80 dB(A)) (Figure 2 left). Regardless of the measuring time, in the press area of the long pasta line (Figure 2 left) and the packaging area of the short pasta line (Figure 2 right), the $L_{EX,Te}$ is between the Upper and Lower $L_{EX,8h}$; in particular, in the packaging area the measures are very close to Lower Level of Action 8h with a daily average level of exposure between 77.2 dB(A) and 83.7 dB(A) which constitute intermediate values (Figure 2 right).

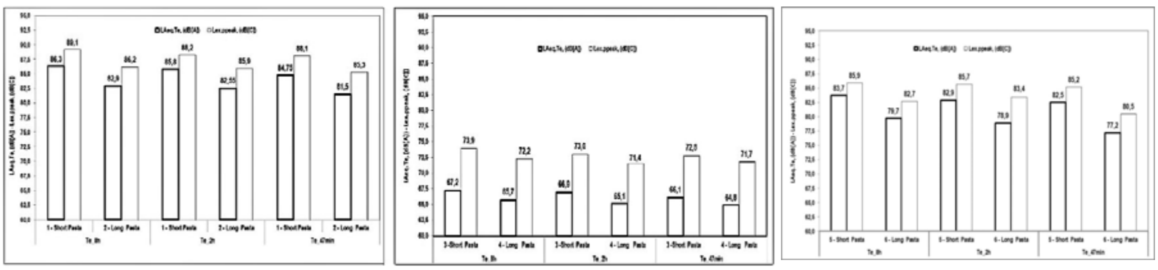

Figure 2: Values of equivalent ($L_{Aeq,Te}$) and impulsive ($L_{EXp,peak}$) noise levels measured in the noise sample points: sample point 1 near short pasta line and sample point 2 near long pasta line (left), sample point 3 near short pasta line and sample point 4 near long pasta line (center), sample point 5 near short pasta line and sample point 6 near long pasta line (right). Mean values of five tests; all the data are significant (p ≤ 0,05)

It is noticeable from the result that the presses area is the noisiest because these machines are used in several operations (feeding, kneading, extrusion die, and cutting) creating acoustic pressure that tends to add up; the noise of the short pasta line is accentuated by the “shaker pre-dryer” where the mechanical stress of the vibrating parts tends to increase the continuous component of the acoustic pressure. As well, the vacuum pump was found to be another source of noise in the press area because it in operation during the whole working cycle of the press. On the other hand, the noise in the packaging area is lower than in the presses area and comparing between short and long pasta packaging machines. Slightly greater noise was noticed in the short pasta, due to the greater operational capacity of vertical packaging machines used in this line, compared with horizontal packaging machines, used in long pasta. The lowest values of noise were measured in the dryer area (Figure 2 center), because all the movements and machinery are kept inside walls with high thermal insulation and, indirectly, also with acoustics: $L_{Aeq,Te}$ is mostly below the Lower $L_{EX,8h}$ (Figure 2 center) with average daily levels of exposure between 76.8 dB(A) and 79.2 dB(A). In the three areas, the measured values on the long pasta line are comparable but always lower than the ones on the short pasta line (Figure 2). Both pasta lines at exposure times of 2 h and 47 min give levels similar to those obtained for 8 working hours, although always lower the difference between the measurements per 8h and 2h is always below 1.0 dB(A), while the differences between the measurements for 8 h and 47 min often exceed 1.5 dB(A); they are much less evident on the long pasta line (Figure 2). The impulse noise is below the lower action level $L_{EXp,peak}$ (135 dB(C)) in the 3 areas, for all exposure times. The high levels of impulsive noise are measured in the press area with around 90 dB(C) which are always inferior to the lower action level values (135 dB(C) (Figure 2 left). It is obvious from Figure 2, that the maximum impulsive noise values are observed always at 8 hours of measurements in the 3 areas and the difference between the other shorter times (2h and 47min) is mostly below 1.0 dB(C), excluding one case of 1.9 dB(C) and another case where the measure relating to 2 h exceeds that relating to 8 h by 0.7 dB(C). Hence, this proves that the impulsive component of environmental noise is not influenced by the period used for measurement and, in all cases, the peak levels can be attributed to occasional factors connected with task organization and machine maintenance and it does not influence the equivalent continuous noise measured at the same sample point. Then, the impulsive noise trend confirms that the noise produced by the machinery is continuous.Dosimeter readings are generally higher than daily noise levels calculated, for each operator, based on exposure times and fixed-point measurements (Figure 3a and 3b) but can be considered comparable. $L_{EX,8h}$ differ less than 0.8 dB(A) in the case of six operators and are lower by about 1.0 dB(A) in two cases (Figure 3a and 3b); this situation is similar also for peak values (Figure 3c and 3d). These results indicate that the dosimeter readings are useful to check the levels of personal noise exposure. Also they confirmed that the workers who operate in the press area are subject to a higher daily exposure level than the people working in the storage/packaging area.

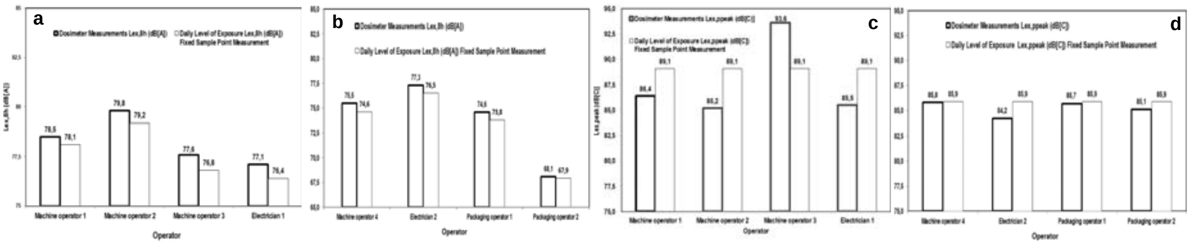

*Figure 3: Values of (daily noise levels ($L_{EX,8h}$) (**a**-**b**) and impulsive noise levels ($L_{EXp,peak}$) (**c**-**d**) measured with personal dosimeters worn by four operators of the machines area (**a**-**c**) and of the silage/packaging area (**b**-**d**) (Fig. 1) compared with those calculated, for the same operators, by measurements at fixed sample points, considering the exposure times. Mean values of five tests; all the data are significant ($p \leq 0,05$)*

4. Conclusions

The choice of the time period for measuring noise levels could assume importance to obtain levels, which once integrated onto the exposure time according to (2), then effectively correspond with the noise exposure during the entire working day; the choice of relatively short exposure times is frequent for professionals in this sector, but should not be excluded the option of taking measurements over longer time periods, if the levels are found to be near the limits. In fact, many of the operators surveyed in this study are subject to average daily level of exposure close to 80 dB(A). Anyway, in specific case, working activity of the workers for which the risk of noise has been assessed is well planned; in fact, their movements allow to avoid staying for long time in areas where their continuous noise exposure can exceed the most critical values. Considering the values of the dosimetric measures, it is evident that the workers are nearer to the machinery, and therefore subject to more noise than the fixed point, expecially in the press area. Then, the readings obtained from the fixed sites are indicative of the environmental noise but they are less indicative of personal exposure and should be compared with dosimetric measures, especially in cases where exposure action values can be achieved.

References

Angulo Á., Tang J., Khadimallah A., Soua S., Mares C., Gan TH., 2019, Acoustic emission monitoring of fatigue crack growth in mooring chains, Applied Sciences,9(11), 2187-2198.

Ayr U., Tamborrino A., Catalano P., Bianchi B., Leone A. 2015, 3D computational fluid dynamics simulation and experimental validation for prediction of heat transfer in a new malaxer machine. Journal of Food Engineering, vol. 154, p. 30-38, ISSN: 0260-8774, doi: 10.1016/j.jfoodeng.2014.12.022.

Becklake M., Broder I., Chan-Yeung M. Recommendations for reducing the effect of grain dust on the lungs, Occupational Health and Industrial Medicine, 1997, 36:2.

Bianchi B., Giametta F., La Fianza G., Gentile A. & Catalano P. 2015, Microclimate measuring and fluid‑dynamic simulation in an industrial broiler house: testing of an experimental ventilation system. Rivista Veterinaria Italiana, Volume 51 (2), April-June, 85-92, doi: 10.12834/VetIt.689.5112.03.

Bianchi B.,2017, Evaluation of ratite skinning force in order to fix plant and mechanical solutions, Veterinaria Italiana, 53(2),131-40.
Caciari T., Rosati MV., Casale T., Loreti B., Sancini A., Riservato R., Nieto HA., Frati P., Tomei F., Tomei G, 2013, Noise-induced hearing loss in workers exposed to urban stressors. Science of the total environment,463-464,302-308.
Canadian Thoracic Society Standards Committee, Canadian Medical Association Journal, 155(10), 1399–1403.
Catalano P., Fucci F., Giametta F., La Fianza G., Bianchi B., 2013, Vibration analysis using a contactless acquisition system, InSensing Technologies for Biomaterial, Food and Agriculture (Vol. 8881, p. 888108). International Society for Optics and Photonics.
Catalano F., Perone C., Iannacci V., Leone A., Tamborrino A., Bianchi B. 2020, Energetic analysis and optimal design of a CHP plant in a frozen food processing factory through a dynamical simulation model. Energy Conversion and Management, 225 (2020), 113444. doi.org/10.1016/j.enconman.2020.113444.
Directive 2003/10/EC, OJ L 42, 15.2.2003. On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (Seventeenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), pp. 38-44.
Giametta F., Catalano P., Gentile A., Perone C., Bianchi B., 2017, A new supporting tool for pig handling in the breeding-slaughterhouse production chain, Veterinaria Italiana, 53(3),197-205.
Huang P., Xu, L., Luo C., Zhang J., Chi F., Zhang Q., Zhou J., 2019, A Study on Noise Reduction of Gear Pumps of Wheel Loaders Based on the ICA Model. International journal of environmental research and public health, 16(6), 999-1032.
IEC 61672-1:2002. Electroacoustics - Sound level meters. Integrating Sound Exposure and Sound Level Meters.
INAIL statistical database 2013-2017.
ISO 1999: 2013. Acoustics -- Estimation of noise-induced hearing loss.
Kozlowski E., Mlynski R., 2019, Selection of Earmuffs and Other Personal Protective Equipment Used in Combination, International journal of environmental research and public health,16(9),1477-1489.
Law Decree No. 81/08 and subsequent modifications and integrations. Italian Official Gazette No. 101/2008 - Ordinary Supplement n. 108.
Leone, A., Romaniello, R., Tamborrino, A., Catalano, P., Peri, G. 2015, "Identification of vibration frequency, acceleration, and duration for efficient olive harvesting using a trunk shaker". Transactions of the ASABE, 58 (1), pp. 19-26. DOI: 10.13031/trans.58.10608.
Merseburger A., 1997, Repetitive movements of the upper limbs: Results of exposure assessment and clinical teste among workers sorting and packing apples, Occupational Health and Industrial Medicine, 37 (2), 74-86.
Nyarubeli IP., Tungu AM., Moen BE., Bråtveit M., 2019, Prevalence of noise-induced hearing loss among tanzanian iron and steel workers: A cross-sectional study, International Journal of Environmental Research and Public Health,16(8),13671380.
Orga F., Alías F., Alsina-Pagès RM., 2018, On the impact of anomalous noise events on road traffic noise mapping in urban and suburban environments, International journal of environmental research and public health. 15(1),13-29.
Passchier-Vermeer W., Passchier WF. 2000, Noise exposure and public health, Environmental health perspectives, 108, 123–131.
Perone C., Catalano F., Giametta F., Tamborrino A., Bianchi B., Ayr U., 2017, Study and analysis of a cogeneration system with microturbines in a food farming of dry pasta, Chemical Engineering Transactions, 20(54),499-504.
Perone C., Fucci F., La Fianza G., Brunetti L., Giametta F., Catalano P., Bianchi B., 2017, Experimental study of a mechanical ventilation system in a greenhouse, Chemical Engineering Transactions, 20(58),811-6.
Stansfeld SA., Matheson MP.,2003, Noise pollution: non-auditory effects on health, British medical bulletin, 68, 243–257.
Tamborrino A., Leone A., Romaniello R., Catalano P., Bianchi B., 2014, Comparative experiments to assess the performance of an innovative horizontal centrifuge working in a continuous olive oil plant, Biosystems Engineering, 129,160-168.
Tamborrino, A., Perone, C., Catalano, F., Squeo G., Caponio, F., Bianchi, B. 2019, Modelling energy consumption and energy-saving in high-quality olive oil decanter centrifuge: Numerical study and experimental validation. Energies 2019, 12, 2592; doi:10.3390/en12132592.
UNI 9432:2011. Acoustics - Determination of occupational noise exposure.
UNI EN ISO 9612:2011. Acoustics - Determination of occupational noise exposure - Engineering method.
Vijayraghavan P., Krishnan R., 1999, Noise in electric machines: A review, IEEE Transactions on Industry Applications, 35(5),1007-1013.