

## Ambient and personal noise exposure assessment in a pasta factory

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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 d 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.

### 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-Vermeer 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 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 (Kozłowski 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.

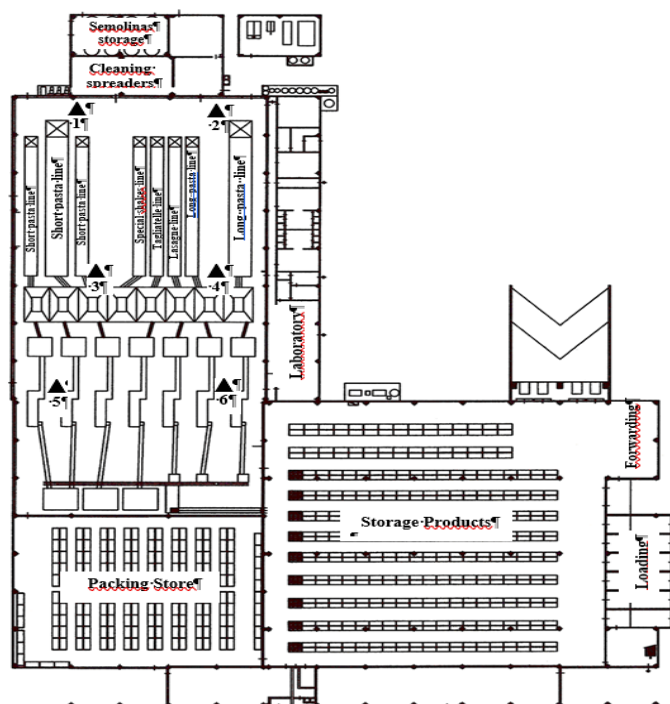


Figure 1: Schematic plan of the pasta factory; the symbols (\*\*\*) indicate the noise fixed sample points. The image is not drawn to scale the second panel

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:

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

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

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

$T_e$  = the time at which the equivalent level is determined, including the daily share of over-time work;  $T_0$  = the reference duration ( $T_0 = 8 \text{ h} = 28800 \text{ s}$ );

$p_0 = 20 \text{ } \mu\text{Pa}$ ;

$p_A$  = 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:

$$L_{EX,8}$$

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

where:  $p_{peak}$  = instant acoustic pressure weighted in Scale C and  $p_0$  = reference acoustic pressure: 20  $\mu$ Pa. 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),  $L_{EX,peak} = 200$  Pa (140 dB (C) in relation to 20  $\mu$ Pa respectively;
- upper exposure action values:  $L_{EX,8h} = 85$  dB(A),  $L_{EX,peak} = 140$  Pa(137 dB(C) in relation to 20  $\mu$ Pa respectively;
- lower exposure action values:  $L_{EX,8h} = 80$  dB(A),  $L_{EX,peak} = 112$  Pa (135 dB(C) in relation to 20  $\mu$ Pa) 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  $T_e$  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).

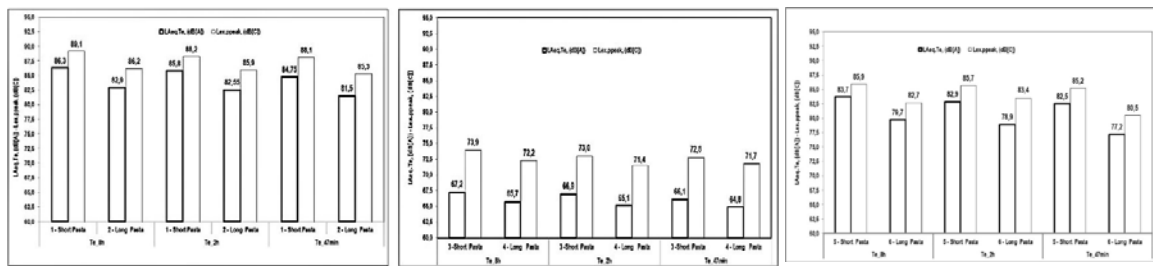


Figure 2: Values of equivalent ( $L_{Aeq,Te}$ ) and impulsive ( $L_{EXP,peak}$ ) noise levels measured in the noise sample points: sample point 1 near short pasta line and sample point 2 near long pasta line (left), sample point 3 near short pasta line and sample point 4 near long pasta line (center), 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  $L_{EX,peak}$  (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.

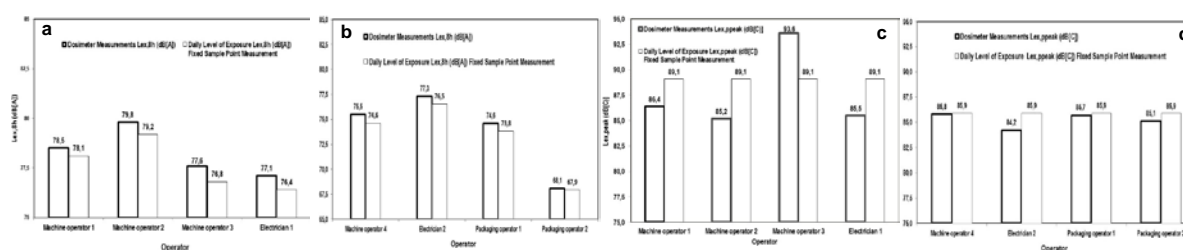


Figure 3: Values of (daily noise levels ( $L_{EX,8h}$ ) (a-b) and impulsive noise levels ( $L_{EX,p,peak}$ ) (c-d) measured with personal dosimeters worn by four operators of the machines area (a-c) and of the silage/packaging area (b-d) (Fig. 1) compared with those calculated, for the same operators,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

#### 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, especially 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.

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