# Noise risk assessment in a bottling line of a modern Sicilian winery

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## Abstract

In wine industry, bottling is a phase of the production cycle characterized by high levels of noise mostly due to repeated collisions between the bottles. In Italy the Law Decree 81/2008 defined the requirements for assessing and managing noise risk, identifying a number of procedures to be adopted at different noise levels to limit workers exposure. This study aims at evaluating the equivalent and peak noise level inside the bottling plant area of a modern Sicilian winery. In particular, the influence of the working capacity (number of bottles produced per hour) on noise levels was evaluated. We considered three test conditions: T1 with working capacity of 4,000 bottles per hour, T2 with working capacity of 5,000 bottles per hour and T3 with working capacity of 6,000 bottles per hour. Fifteen measurement points were identified inside the bottling area. The instrument used for the measurements is a precision integrating portable sound level meter, class 1, model HD2110L by Delta OHM, Italy. The tests were performed in compliance with ISO 9612 and ISO 9432 regulations. The results show that as bottling plant working capacity increases, noise level increases. The measured sound levels exceed the limits allowed by the regulations in all the test conditions; values exceeding the threshold limit of 80 dB(A) were recorded coming up to a maximum value of 95 dB(A) in test T3. In this case, the operator working along the bottling line is obliged to wear the appropriate Personal Protective Equipment.

## Introduction

In wine industry, bottling is a phase of the production cycle characterized by high levels of noise (Lowe and Elkin, 1986; Ologe *et al.*, 2008; Oyedepo and Saadu A., 2010) mostly due to repeated collisions between the bottles. Bottle transport has been identified as one of the main noise-sources in bottling plants (Sivak, 1982); the noise is emitted from the clashing bottles.

Directive 2003/10/EC of the European Parliament was enacted on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise).

It stipulates an upper average limit of noise exposure of a worker during an eight hours shift of work at 85 dB(A). This level is supposed to inhibit hearing impairments of workers (Moselhi *et al.*, 1979). Even the ILO (International Labour Organization) indication agree with this.

In Italy, Law Decree 81/2008 has defined the obligations of noise assessment and risk management, identifying a series of procedures to be adopted at the different noise levels in order to limit the exposure of workers. Excessive noise, in fact, is a global occupational health hazard with considerable social and physiological impacts, including noise-induced hearing loss (NIHL) (Deborah *et al.*, 2005).

Some authors carried out researches aiming at evaluating innovative systems to implement the control of multi-lane conveyors in bottling plants for a noise level reduction. In particular, Sorgatz *et al.* (2012) developed a continuous control algorithm to further reduce the noise emission of multi-lane bottle conveyors. They obtained that the continuous control is less noisy compared with the jam switch control evaluating noise in five measuring points because with the innovative system the velocity of the belts decreased and the impact velocity of the bottles reduced.

In literature, there are few studies concerning the noise level assessment in a bottling plant of a winery. Therefore, this study aims at evaluating the equivalent and peak noise level inside the bottling plant area of a modern Sicilian winery. In particular, the influence of the working capacity (number of bottles produced per hour) on noise levels was evaluated.

## Materials and methods

### Bottling plant

The bottling plant examined in this study is automated, schematically consisting of the following machines:
- depalletizer (loading empty bottles);
- washing - filling – capping machine;
- washing and drying machine (cleaning the outside of the bottle);
- capper;
- labeling machine;
- vertical cartoner;
- forming machine;
- hive inserting machine;
- closing machine;

- pallettizer;
- wrapping machine.

Five operators control the different phases of the process.

**Instruments used during the tests**

The instrument used in the tests is a precision integrating portable sound level meter by Delta OHM, Italy, model HD2110L (Figure 1).

## Experimental tests

The winery bottling area has an almost rectangular plant with an area of approximately 800 m$^2$. The 15 measurement points were located through a square mesh whose sides are orthogonal with respect to the sides of the room (Figure 2).

The sound level meter was positioned at a height of 1.50 m from the ground with the aid of a tripod; each measurement had a duration of 2 minutes (the case of stationary noise source) and the parameters were analyzed at intervals of 0.5 seconds.

We measured A-weighted time-averaged sound pressure level ($L_{Aeq}$) and C-weighted peak sound pressure level ($L_{Cpk}$). In addition, a C-weighted ex post measurement in the point of greatest noise was realized.

As required by article 189 of Law Decree 81/2008, the worker does not have to be exposed to $L_{Eex,8h}$ values (occupational noise) reported to 8 working hours higher than 80 dB(A) and to $L_{Cpk}$ exceeding 135 dB(C).

$L_{Eex,8h}$ values is given by the following equation:

$$L_{EX,8h} = L_{Aeq,Te} + 10 \log (T_e / T_0)$$

where Te is the effective duration, in hours, of the working day and $T_0$ is the reference duration equal to 8 hours. In this case Te was assumed to be 7.5 hours.

Before each series of measurements the instrument calibration was performed applying a sound calibrator. The collected data were downloaded to the PC for further processing.

Three test conditions, corresponding to different bottling plant working capacity (as number of bottles per hour) were realized, named T1, T2 and T3:

- T1: working capacity 4,000 bottles per hour;
- T2: working capacity 5,000 bottles per hour;
- T3: working capacity 6,000 bottles per hour.

Tests were carried out in triplicates. Analysis of variance and Tukey's test were performed using Statgraphics Centurion by Statpoint inc., USA.

## Results and discussion

A-weighted time-averaged sound pressure levels ($L_{Aeq}$) for test T1 are shown in Figure 3 for the 15 measuring points.

Noise pressure values obtained in T1 show a minimum of 82.4 dB(A) in the measurement point number 7, near to the palletizer, and a maximum of 89.6 dB(A) in the measurement point number 13, which is located immediately before the capping machine. Figure 3 shows that the exposure limit value established by the article 189 of Law Decree 81/2008 (equal to 87 dB(A)) is reached only in measurement points number 4 and 13 which are located in the vicinity of the conveyor bends. The upper action value of 85 dB(A) is instead achieved in all the measuring stations with the exception of 2, 7, 8, 10 and 14 while the lower action value (equal to 80 dB(A)) is exceeded in all the measuring points. Statistical analysis (p < 0.05) shows significant differences between all the measuring points with the exception of 1-12, 1-3, 8-10, 3-12, 6-12, 5-15.

Figure 4 shows the A-weighted time-averaged sound pressure levels ($L_{Aeq}$) for test T2.



Figure 1. HD2110L integrating portable sound level meter by Delta OHM, Italy.
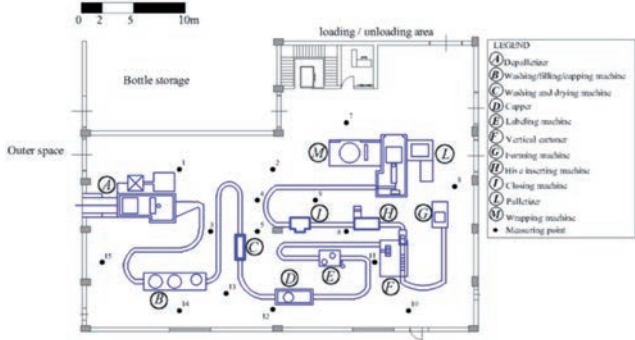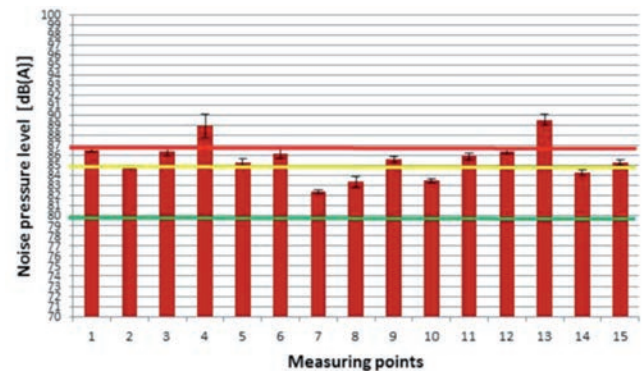


Figure 2. Plan lay out of the bottling area and measurements points.



Figure 3. Noise pressure levels ($L_{Aeq}$) for test T1 in the 15 measuring points (data are reported as means ± standard deviations of the three replicates).

Noise pressure values obtained in T2 show a minimum of 83.8 dB(A) in the measurement point number 7, near to the palletizer, and a maximum of 93.4 dB(A) in the measurement point number 4, which is located immediately after the closing machine. The exposure limit value is reached in measurement points number 3, 4, 5, 9, 11, 12, 13 and 15. The upper action value is achieved in all the measuring stations with the exception of number 7 while the lower action value is exceeded in all the measuring points. Statistical analysis (p < 0.05) shows significant differences between all the measuring points with the exception of 2-6, 2-14, 5-15.

Figure 5 shows the A-weighted time-averaged sound pressure levels (L$_{Aeq}$) for test T3.

Noise pressure values obtained in T3 show a minimum of 84.5 dB(A) in the measurement point number 7, near to the palletizer, and a maximum of 95.6 dB(A) in the measurement point number 4, which is located immediately after the closing machine. The exposure limit value is reached in all the measurement points with the exception of 7, 8 and 10. As obtained in T2, the upper action value is achieved in all the measuring stations with the exception of number 7 while the lower action value is exceeded in all the measuring points. Statistical analysis (p < 0.05) shows significant differences between all the measuring points with the exception of 1-2, 1-9, 1-14, 2-9, 2-14, 9-14, 9-15, 14-15.

Data related to the three tests are reported together in Figure 6 in order to highlight the differences, if any, between the noise levels achieved in the various measurement points. Always note statistically significant differences for p = 0.05 between the tests T1-T2 (with the exception of the measuring point 6) and T1-T3. The comparison between T2 and T3, however, shows that not all the measurement stations are statistically significant different. Differences were found, for example, at station 4, but not in 13.

The spectral analysis regarding the measurement stations 4 and 13 is reported in Figure 7 for the three test conditions.

C-weighted peak sound pressure levels (L$_{Cpk}$).obtained in the different tests are shown in Figure 8.

Neither the exposure limit value equal to 140 dB(C) according to the cited art. 189 of Law Decree 81/2008, or the upper and lower action values (equal to 137 dB(C) and 135 dB(C)) are reached or exceeded in any of the measurement points. No statistically significant differences were found between the three tests.

The data obtained by the measurements allowed us to have the equal loudness curves for the tests carried out, thereby evaluating the zones with equivalent average sound levels. Figure 9 shows the map related to T1.

With reference to T2 (Figure 10), you may notice an increase in the noise level compared to T1.

The results of T3 (Figure 11), show overall noise levels higher than the two test conditions discussed above.

## Conclusions

The results of the experiments carried out allow us to affirm that increasing the bottling plant working capacity the noise level increases. The highest noise pressure values were obtained in the measurement point number 4 and 13, respectively located immediately after the closing machine and before the capping machine; this occurs in the three test conditions. The results also show that noise pressure values measured during the three tests are always higher than the lower action value identified by law, equal to 80 dB(A) In particular, the upper action value equal to 85 dB(A) is reached in all the measurement points except 2, 7, 8, 10 and 14 in T1. In T2 and T3 this value is reached in every station except number 7. The exposure limit value of 87 dB(A) is reached in T1 only in the stations 4 and 13, in T2 in 3, 4, 5, 9, 11, 12,

13 measurement points and in T3 in all the stations except 7, 8 and 10. As a consequence, the use of appropriate PPE is required when limits imposed by the regulations are exceeded.

With reference to the peak values, neither the exposure limit value equal to 140 dB(C), or the upper and lower action values (equal to 137 dB (C) and 135 dB (C)) are reached or exceeded in any of the measurement points.
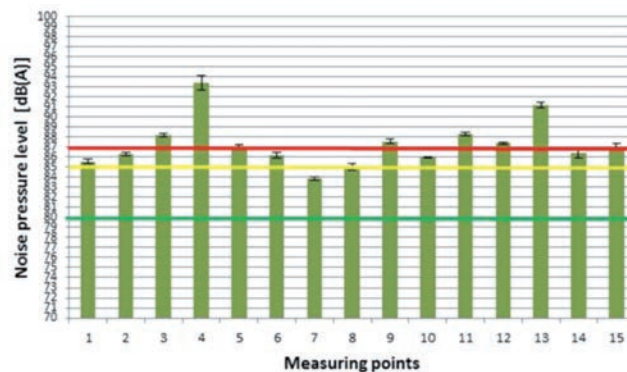


Figure 4. Noise pressure levels (L$_{Aeq}$) for test T2 in the 15 measuring points (data are reported as means ± standard deviations of the three repli-
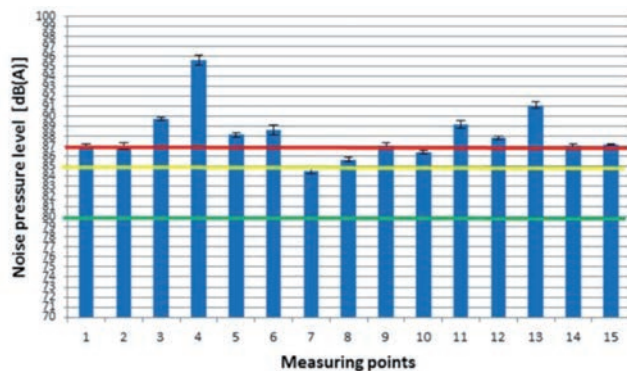


Figure 5. Noise pressure levels (L$_{Aeq}$) for test T3 in the 15 measuring points (data are reported as means ± standard deviations of the three replicates).
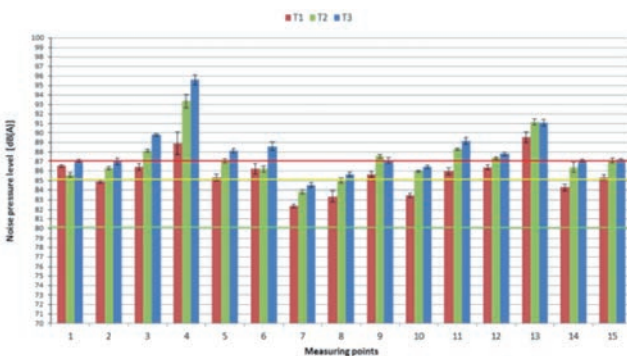


Figure 6. Noise pressure levels (L$_{Aeq}$) for tests T1, T2 and T3 in the 15 measuring points (data are reported as means ± standard deviations of the three replicates).
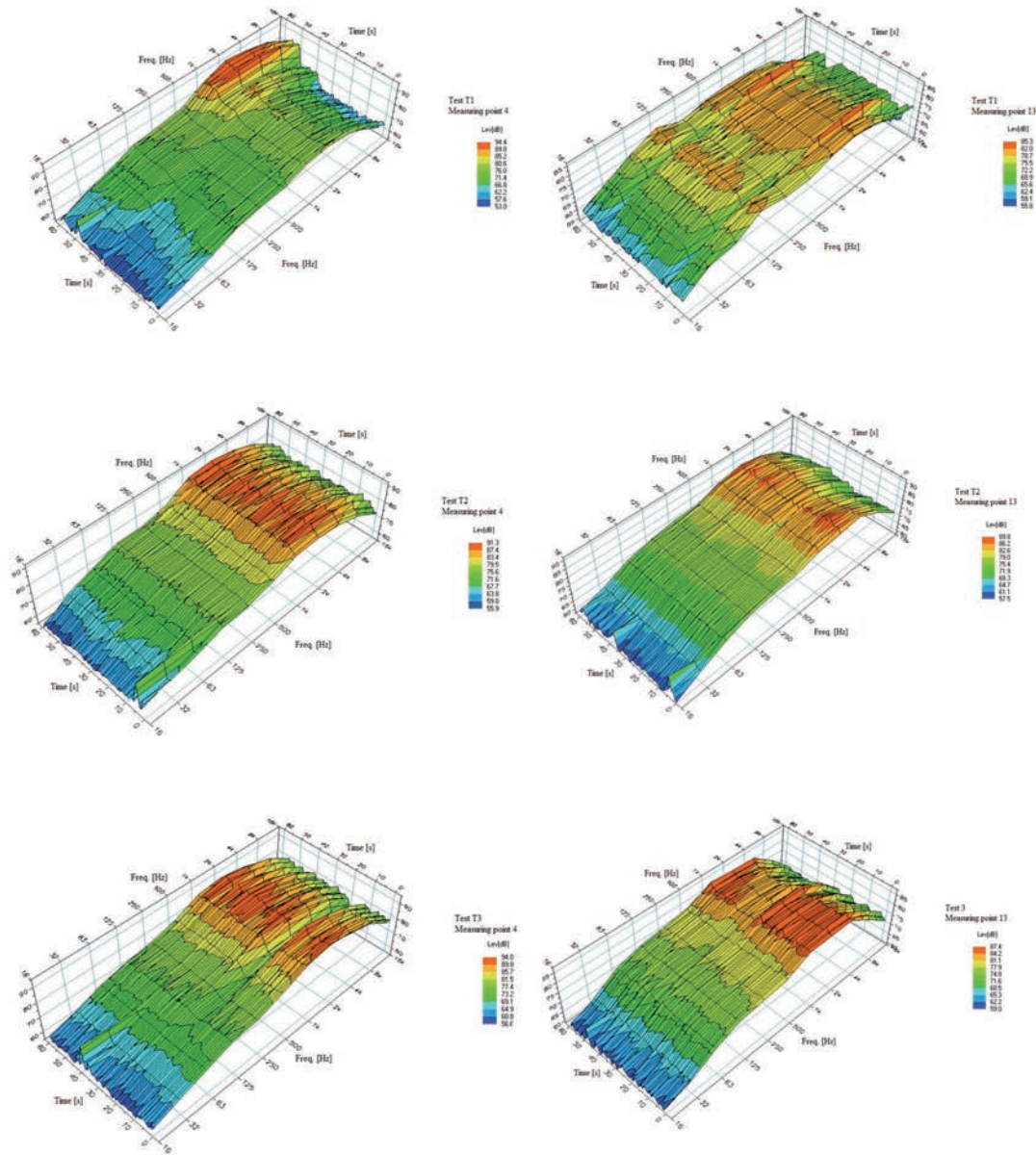
**Figure 7. Spectral analysis regarding the measurement stations 4 and 13 for T1, T2 and T3.**
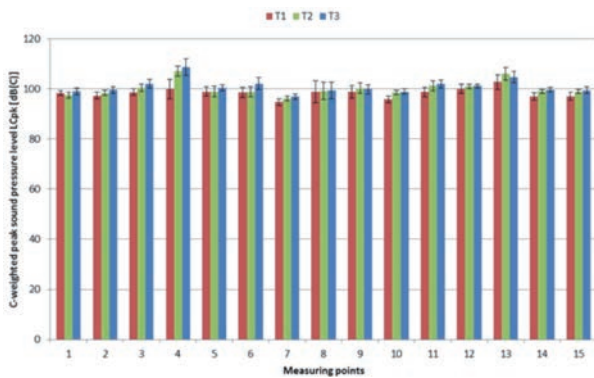


**Figure 8. C-weighted peak sound pressure leves ($L_{Cpk}$).obtained in the tests T1, T2 and T3.**
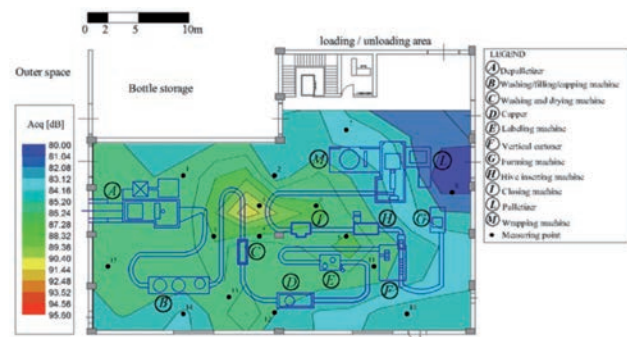


**Figure 9. Map of equal loudness curves for test T1.**
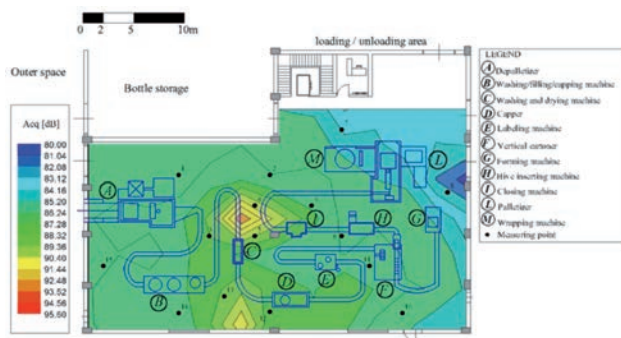
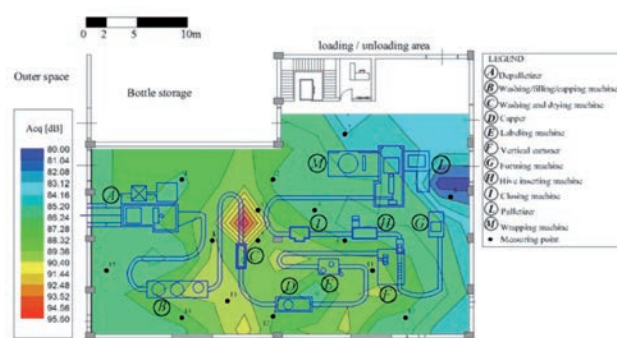Figure 10. Map of equal loudness curves for test T2.



Figure 11. Map of equal loudness curves for test T3.

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