Methods of validation of occupational noise exposure measurement with multi aspect personal sound exposure meter

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ABSTRACT

Occupational noise measurement over the full working day is usually performed using personal sound exposure meters (noise dosimeters). As workers carrying a dosimeter inevitably disturb the measurements, (whether willingly or unwillingly), it can be a challenge to validate results and ensure they are representative of the actual occupational noise exposure. This paper reports on a case study of mechanical workshop noise measurement. Evaluation of daily occupational noise exposure is impeded by non-occupational sound source events, for example "faked" increases in noise level achieved by putting the dosimeter immediately adjacent to the working tool and accidental bumps and scrapes of the microphone against solid surfaces. As shown in this paper, with newer generation, "smart" dosimeters, it is largely possible to eradicate such distortions and thereby achieve a better estimate of the actual occupational noise exposure.

1. INTRODUCTION

With mobile workers, undertaking many noise-related tasks or subject to unpredictable work patterns, standards like ISO 9612:2009 advise the use personal sound exposure meters (PSEM) and a full-day measurement strategy for evaluation of daily occupational noise exposure.

Inevitably in this approach, some workers wearing PSEM will disrupt the measurements (willingly or unwillingly), thus it is recommended that the specialist responsible for the evaluation, constantly observe the workers. However, as such measurements can take two or more workdays to complete and may need to be performed in harsh conditions; this recommendation is often not followed, with a resulting increased uncertainty as to the actual occupational noise exposure.

With the new “smart” PSEM devices, which log not only short L_{Aeq} time history, but also the frequency spectrum, record audio and track of mechanical shocks to the meter and permit detection of time periods where the worker removed the meter – it is possible to exclude many cases of distortion and therefore achieve better estimates of daily noise exposure. The current study presents an analysis of the potential impact of:

- noise of non-occupational origin,
- apparent amplification of the occupational exposure due to the PSEM being removed by the worker and “parked” adjacent noisy machinery
- accidental bumps of meter’s microphone against hard surfaces,

on the estimation of daily occupational noise exposure.

2. METHODS

The study was performed using a SVANTEK SV 104, personal sound exposure meter. The SV 104 meets Class 2 IEC 61672:2002 and was designed to perform measurements in accordance with ISO 9612, ACGIH, NIOSH, OSHA and numerous other occupational noise standards. In addition to L_{Aeq}, L_{Ceq}, L_{Cpeak}, L_{AVG}, TWA etc., the meter is capable of logging short period time histories of 1/1 octave band spectra, record audio events or record audio continuously. The output of a built-in tri-axis accelerometer is logged during measurement thus allowing mechanical shocks which the meter (and its microphone) may receive to be recorded for later identification. This facility also permits those periods when the device was motionless to be detected (such as might occur, if the PSEM was removed by the worker and “parked” somewhere).

The logging results were analysed using SVANTEK Supervisor software. This provides various tools to evaluate occupational noise exposure and allow detection and separation of measurement distortions, using data recorded on the PSEM.

Figure 1: SV 104

A full working day (approximately 7 hours) measurement was conducted in a mechanical workshop. Activities included CNC machine operation, metal sawing and grinding operations. The worker had two SV 104 installed on both shoulders. The PSEM was set to log at 500 ms intervals. An audio event recording trigger level of 85 dBA short L_{Aeq} was used.

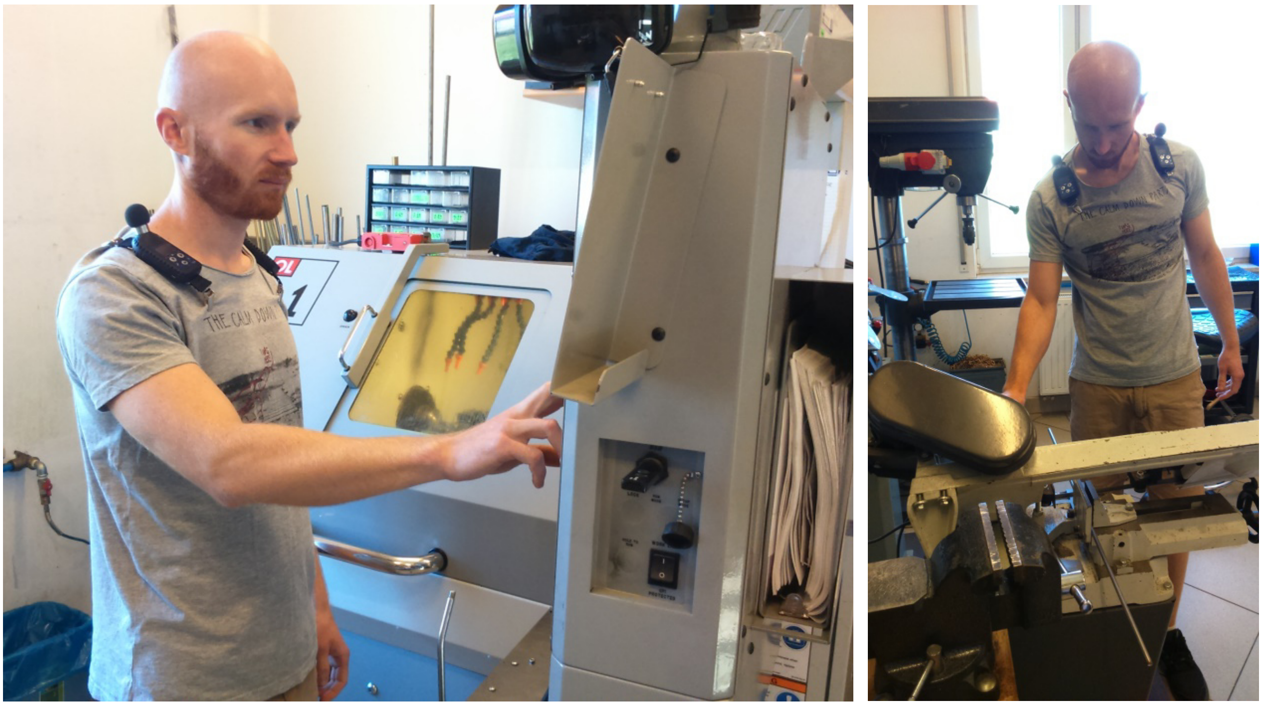

Figure 2: Workshop worker operating CNC machine (left) and saw (right)

The operator listened to loud music occasionally to simulate noise exposure increase due to non-occupational sources. During the measurement period, the PSEM on the left shoulder was bumped against hard surfaces in the workshop multiple times, to check the impact of such shocks on measurement results.

The left hand device was also removed from the workers shoulder twice, for an overall period of approximately 1 hour 12 minutes. During these periods the PSEM was "parked" on top of the CNC machine to simulate worker manipulation of the apparent daily occupational noise exposure.

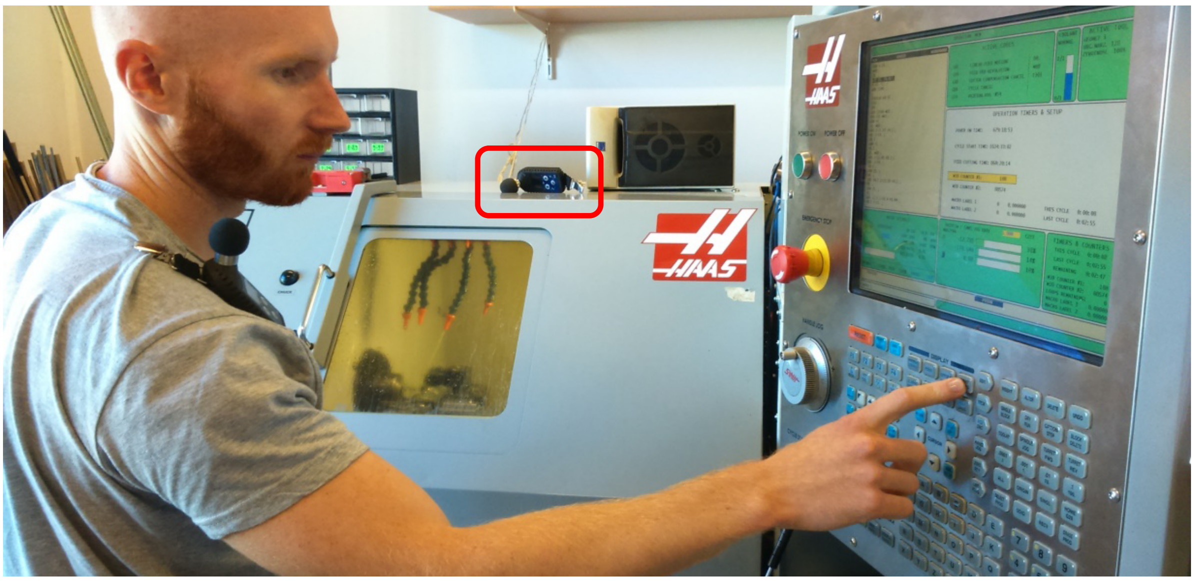

Figure 3: Worker operating CNC machine, left shoulder PSEM detached and positioned on CNC chamber

3. RESULTS

The measurement "shift" was 7 hours 13 minutes. The "raw" results obtained (without further analysis to remove periods where the measurements were subject to distortion) are summarised in Table 1. As may be noted, the left shoulder PSEM recorded a Noise Dose which was 106 % of the allowable dose.

Table 1: Summary results of the measurement, without eliminating disturbances

Instrument	L_{Aeq} (dBA)	DOSE (%)	L_{Cpeak} (dBC)
Right shoulder	74.1	7.3	120.8
Left shoulder (+ distortions)	85.7	106.1	>140

3.1 Introduced Music Noise

As noted above, the measurement results from both instruments were influenced by loud music. Figure 4 shows a typical view of the analysis software output screen.

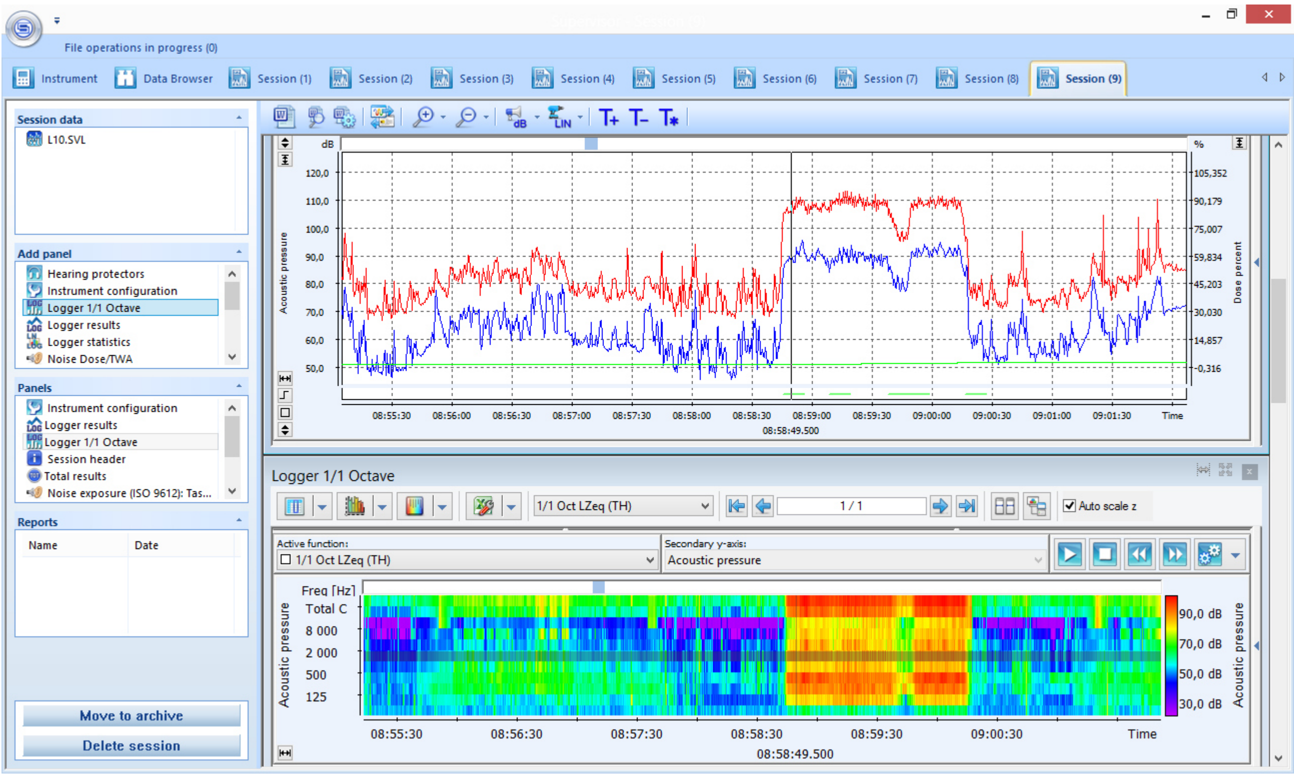

Figure 4: Time history of L_{Aeq} and L_{Cpeak} together with a spectrogram of a loud music event, left shoulder instrument

Two short period loud music events (2 minutes 26 seconds in total) from the left shoulder instrument time history stand out due to their different frequency characteristics relative to those typical for workshop tools. The loud music resulted in an increase in the daily dose of 1.3 percentage points (L_{Aeq} 89.9 dBA for 2 minutes 30 seconds). Apart from the spectral differences, music events can be identified by playback of the audio events logged by the PSEM.

3.2 PSEM parked adjacent operating machinery

Two periods of no movement were noted in the left shoulder PSEM record, these are highlighted with an orange marker in the time history shown in Figure 5. The periods sum to a total of 1 hour 12 minutes and are responsible for 13.7 percentage points of the daily dose. The events shown can be matched to the period of time when the instrument was removed by the worker and placed on top of the CNC chamber.

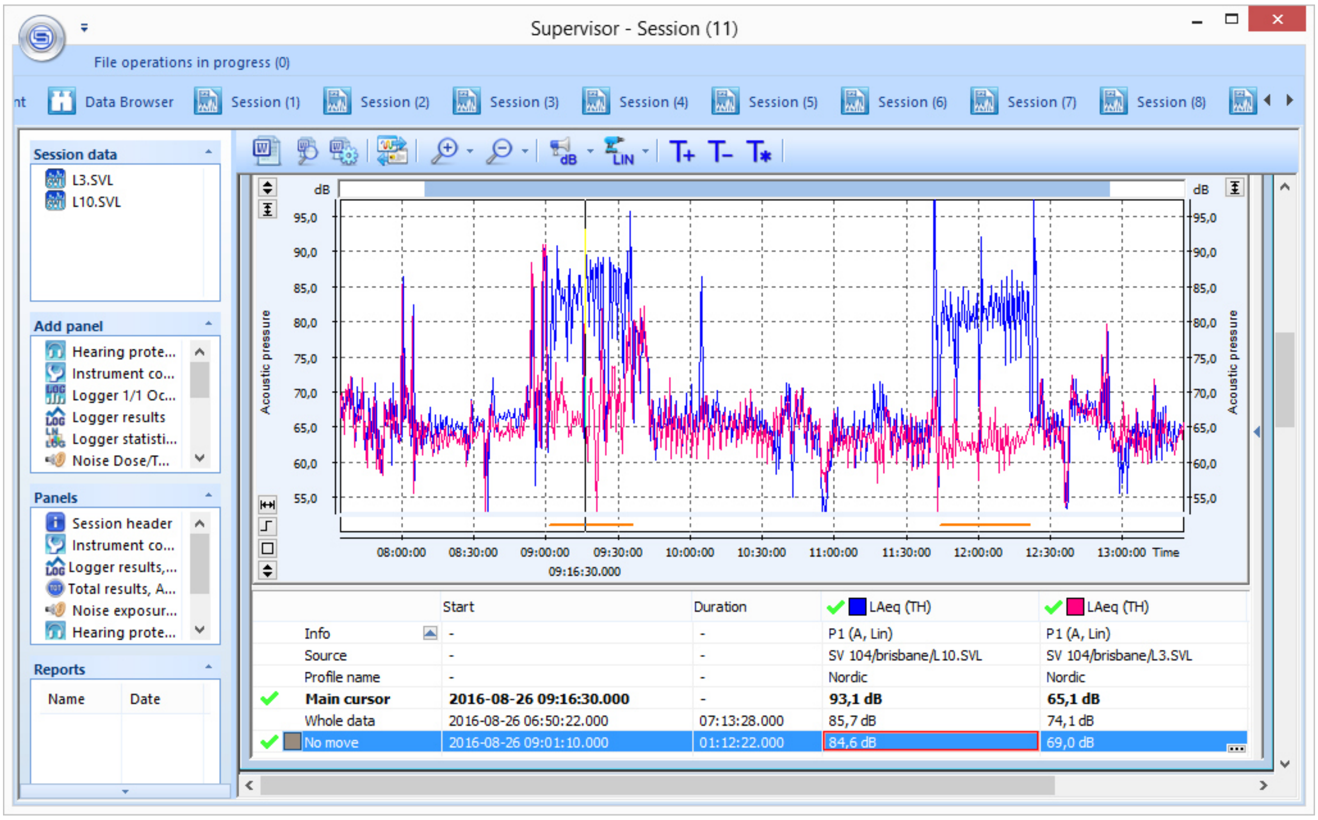

Figure 5: Full day measurement L_{Aeq} overview from both instruments

Figure 5 allows comparison of the time history from the left and right shoulder PSEM. Left shoulder – blue trace, including those periods where the meter was removed and placed on top of the CNC machine (L_{Aeq}, average over the 1 hour 12 minutes period was 84.6 dBA) and right shoulder – red trace (remaining on the worker's shoulder, average L_{Aeq}, over the same period, 69.0 dBA). During the period, the worker remained within 0.5 – 2.5 m of the CNC machine.

3.3 Bumps against hard surfaces

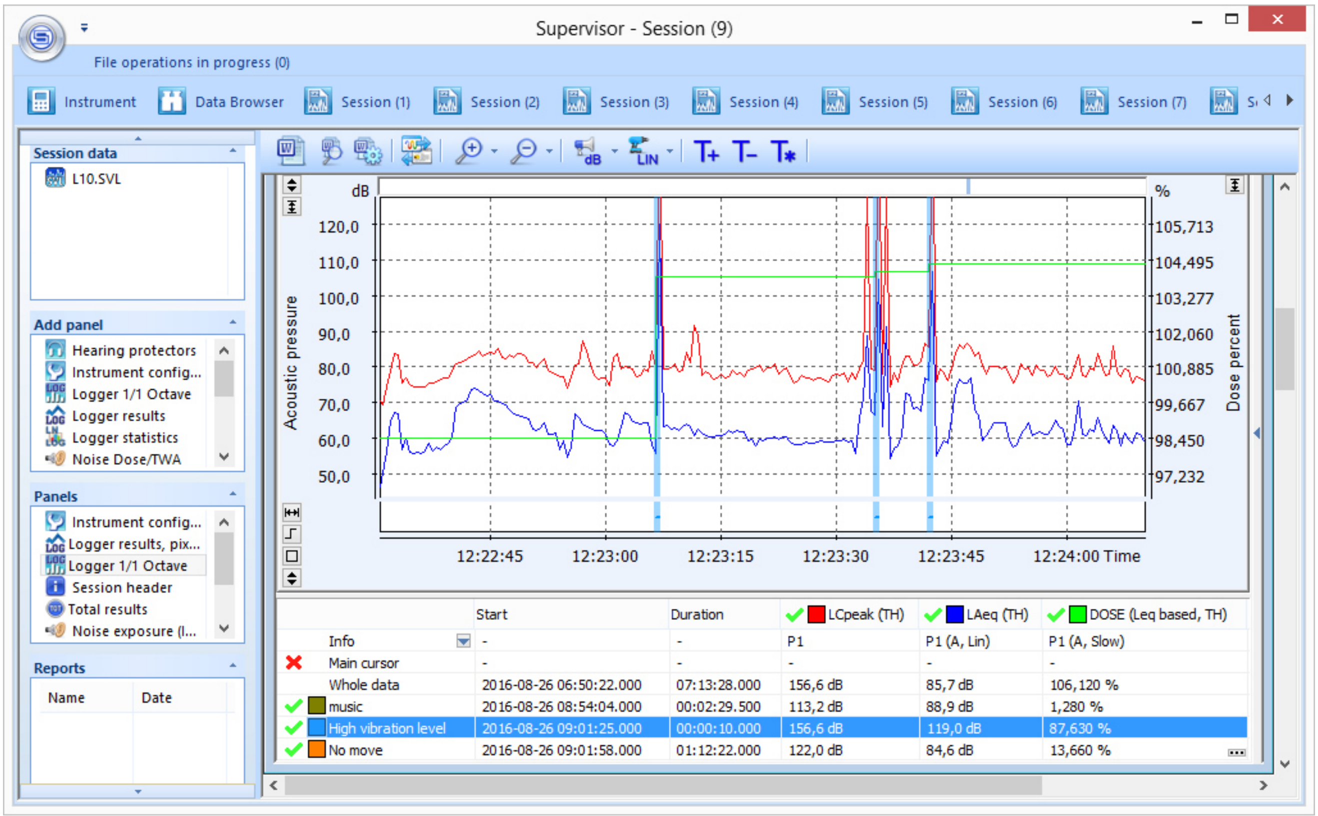

Figure 6: Left shoulder PSEM: three mechanical shocks, L_{Aeq} and L_{Cpeak} time history

Three example bumps to the instrument, labelled in blue as “High vibration level” are pictured with Figure 6. The bumps together add 5.9 percentage points of the daily allowable dose. During the approximate 7 hour period a total of 17 “High vibration level” events were automatically marked by the PSEM. These events were responsible for 87.6 percentage points (of 106.1 % of the allowable dose) in the exposure measurement.

However, in a real situation, where the software tool indicates a “High vibration level”, suggesting that a particular recorded peak sound pressure level event is more than likely an artefact, that impacted only the microphone, (not the workers ear), it is still advisable to discuss the situation with the worker and confirm the finding, as a true impulsive noise (rather than an artefact from the microphone being bumped) may be especially harmful.

In the current experiment, some of the stronger bumps the instrument received, would likely damage a classic condenser/ceramic microphone. However, the SV 104 is equipped with an extremely robust MEMS technology microphone and no sensitivity shift occurred during this experiment. This was verified by comparing pre and post-measurement calibration factors. Calibration was performed with a SVANTEK SV 35 Class 1 calibrator at 114 dB sound pressure level. The observed calibration drift was 0.02 dB.

3.4 Summary and final estimation of daily occupational noise exposure

The effect of the three kinds of distortions considered in this experiment can be seen in Figure 6. This table is derived from the Supervisor analysis software outputs (which are presented in a table below the time history plot).

The measurements were started at the beginning of the worker’s shift and stopped at its end, 7 hours and 13 minutes later, thus this period can be treated as the exposure time. The duration of observed distortions in this particular case should not be removed from the exposure time, as it is known that the worker remained at his post throughout the entire period. After eradicating the various “distortions”, the final daily occupational noise exposure $L_{EX,8h}$ was calculated (as an output of the Supervisor software) as 71.3 dBA (L_{Aeq} 71.8 dBA for 7 hours 13 minutes), which is 4.3 % of allowable dose (criterion level: 85 dBA for 8 hours working day).

Table 2: Impacts of distortions, left shoulder instrument

Factor	L_{Aeq} (dBA)	Duration	DOSE (%)
Music	88.9	2 min 30 sec	1.3
No movement	84.6	1 hour 12 min	13.7
Bumps	119.0	10 sec	87.6
Whole measurement	85.7	7 hours 13 min	106.1

4. CONCLUSION

As discussed in this paper, sound which is non-occupational in origin can affect occupational noise exposure measurements quite noticeably. There is thus a need to be able to identify it. The instrument studied allows this to be done visually via a spectrogram and also by audio playback of the recorded events.

Manipulated noise level increase from occupational tools achieved by positioning the instrument closer to machine is difficult to identify, as it has the same frequency characteristics as more usual exposures and also sounds similar in playback to recordings made where the PSEM (and the worker's ear) are in close proximity to an occupational noise source such as during tool usage. This is where the logged output from a motion sensor can be very helpful in identifying, suspect periods of measurement.

The effect of bumps to the PSEM and microphone for the assessed exposure can be very large. It is thus important to be able to distinguish between high sound pressure level events actually heard by the worker and those apparent events which affect only the microphone and which should be removed from the time history when evaluation of the true daily occupational noise exposure is to be made.

REFERENCES

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