

Determining School Music Teachers' Noise Exposure



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Abstract

Hearing loss claims made by two school music teachers sparked this study. Music teachers are exposed to intense instantaneous sound levels but long-term reliable $L_{Aeq,T}$ s were previously unavailable. Their hearing risk was considered minor compared to industrial workers' but exists since they are exposed to intense sounds daily and have reduced tolerance for NIHL.

All music teachers in a School District were surveyed daily for several days. Teachers maintained daily activity logs. It was clear that to obtain a complete record would be lengthy due to departures from the teachers' timetables through illness, staff meetings etc. Dosimetric data were downloaded, edited for artifacts and matched with log entries. A database of $L_{Aeq,T}$ by lesson-type was compiled. Teachers' noise doses were synthesized by activity over the timetables from their $L_{Aeq,T}$ s by lesson-type. Where lesson-types were unsampled, $L_{Aeq,T}$ s from the database were substituted. L_{EX} s were obtained by normalizing $L_{Aeq,T}$ to the industrial work pattern.

Introduction

Teachers of school band and choir experience sound levels higher than other professionals. Their noise exposure levels have not been known with a high degree of precision. High instantaneous or short-term average sound levels have been reported (Refs. 1 & 2). One reason for the lack of information was due to the impression that teachers' daily noise exposure varied considerably from day to day. This meant that a reliable noise exposure level of the profession over the long term (such as for hearing loss claim evaluation) would require a considerable noise survey effort, resources for which were scarce. Also, short-term sampling from the early 1980s indicated exposure levels were well below our (then) regulatory limit of 90 dBA for an 8 hour day in British Columbia (Ref. 3).

By a fortunate coincidence the services of two university engineering co-op students were available for field work at the same time a School District contacted the WCB for help over another music teacher's claim for NIHL. The teacher's exposure was described as 1½ hours/day music teaching for 6 years. Our noise survey was therefore undertaken with the cooperation of the School District and all its ten music teachers over a period of two weeks from seven schools.

WCB Noise Exposure Limits

The principal noise exposure descriptor in current use in British Columbia is the L_{EX} (or $L_{EP,d}$). This is the A-weighted equivalent steady sound level which, over 8 hours, has the same noise dose as that actually acquired in the entire work shift, $L_{Aeq,T}$. In practice, the equivalent sound level, $L_{Aeq,T}$, is measured by dosimetry over a duration, T hours. If the sample obtained in time T is representative of the noise level of the entire shift, then $L_{Aeq,T} = L_{Aeq,Tshift}$. The L_{EX} is then obtained by applying a "correction" to the measured $L_{Aeq,T}$ for "shifts" other than 8 hours in length:

$$L_{EX} = L_{Aeq,T} + 10 \log_{10} \{ T_{shift}/T_0 \} \quad \text{dBA} \quad (\text{Equation 1})$$

where:

- $L_{eq,T}$ = L_{eq} over the sampling period, T_{sample}
- T_{shift} = shift duration
- T_0 = criterion shift duration = 8hours = 480 minutes

L_{EX} , normalizes the exposure of workers to the 8 hour day industrial standard. Thus, the L_{EX} of workers whose regular exposure to noise is about 5 hours per day would be 2 dB less than their measured $L_{Aeq,T}$. The L_{EX} , descriptor is preferred by the WCB since International Standards Organization Standard ISO 1999(1990) (Ref. 4) predicts hearing loss using $L_{EP,d}$ or its equivalent, L_{EX} .

Instrumentation & Method

Personal noise dosimeters, Bruel & Kjaer Type 4436, were used to monitor the daily noise exposure of each teacher. One useful feature of this instrument is its data "logging" capability - the instrument records the sound level-time history to which the wearer is exposed over an entire workday. The dosimeter can download the history as a record of 1-minute or 10-minute L_{Aeq} , Maximum "Slow" level and Maximum "Peak" values.

The schools were assigned to the engineering students such that each school could be visited by one of the students after class. The students collected a dosimeter from each teacher's pigeon hole, downloaded its contents to a laptop computer, checked the dosimeter's calibration and fitted a fresh battery. The teacher's activity log was collected. The dosimeter was returned to the teacher's "pigeon hole" for the next day along with a blank activity log. The following morning, teachers clipped on their dosimeters locating the microphone in the "hearing zone" over one shoulder, turned them "On" and set them to "Run" and wore them throughout the day. At the end of the day, the teachers left the instruments (still "on") in their "pigeon hole" with a completed log of the day's activities. Examples of a single day's and several consecutive days' dosimetry are shown in Figures 1 & 2 (Appendix).

A useful parameter computed by the Type 4436 is the $L_{Aeq,T}$ -related quantity called "PSEL" (Ref. 5). The PSEL is the constant equivalent sound level which, if lasting for eight hours, would produce the same noise dose as that obtained in the sampling time, i.e.:

$$PSEL = L_{Aeq,Tsample} + 10 \log_{10} \{ T_{sample}/T_0 \} \quad \text{dBA} \quad (\text{Equation 2})$$

where:

- T_{sample} = duration of sampling period
- $L_{Aeq,Tsample}$ = L_{Aeq} over the sampling period, T_{sample}

The PSEL is a TWA with $q = 3$ dB exchange rate.

In general, $PSEL \neq L_{EX}$. Only in the special case for sampling over the entire shift is PSEL equal to L_{EX} . In this project, the dosimeters accumulated the noise dose each day starting before class each morning and ending after class each afternoon. Each working day's length was variable but immaterial, through the PSEL the exposure was standardized to the criterion shift length of eight hours. Also, as each sample contained the teacher's entire day's occupational noise, $PSEL = L_{EX}$. Therefore, by noting the PSEL as giving the L_{EX} , the question of the teachers' daily shift duration was avoided which also avoided the application of Equation 1.

The students noted the PSEL and downloaded the dosimeters' contents to their laptop computer. The PSEL was recorded as a measure of the teachers' noise exposure for that day.

Analysis from "Raw" PSEL Data

A fast method to estimate the L_{EX} is to average all daily PSEL values. It soon became clear representative samples of "typical" and complete day exposures would be more difficult to collect than originally envisaged. When the week's data were reviewed about half the data had been missed or rejected for various reasons (sickness - it was the 'flu season, a Professional Development day, ad hoc staff meetings, rehearsal for special presentation and dosimeter misuse). The standard deviation of the raw PSEL data was analyzed using Canadian Standard Association's Draft Standard CSA Z107.56 (Ref. 6). It was clear that more samples were required to attain the desired precision of ± 2 dB. Also too few music classes of certain types were collected. Surveying continued into the second week. Eventually, forty complete teacher-day PSELs were acquired, the standard deviation of which suggested acceptable precision. The data is summarized in Figure 3, individual PSELs are not shown as the PSELs obtained from each teacher ranged in number from 1 to 6.

A correction of -1 dB was applied to measured daily PSELs, to normalize the L_{EX} to the standard 50 week work year (teachers' work year is 40 weeks).

		Sound Exposure Level, L_{EX} , dBA		
Teacher's initials	Teacher designation (full/part-time)	"Raw" PSEL data	"Refined" PSEL data	Data base Synthesis
SW	Full-time Band		90.5	86.6
RA	Full-time Band		80.9	84.0
RK	Full-time Band		82.7	81.9
KO	Full-time Band		90.0	91.1
TK	Part-time Band		85.5	84.2
MS	Part-time Band		94.1	89.9
KW	Part-time Band		85.2	87.6
DI	Full-time Choir		83.4	84.5
FR	Full-time Choir		85.2	87.0
NM	Part-time Choir		73.5	78.1
Average, dBA		84.5	85.1	85.5
Standard deviation, dB		6.4	5.7	3.8

Number data points	40	10	10
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Figure 3. Summary of school music teacher noise exposure results

Analysis using “Refined” PSEL Data

To reduce the standard deviation, teacher noise histories were examined and adjusted thus:

- any $L_{Aeq,10min}$ sample with peak levels > 140 dB (Lin) were deleted and the PSEL recalculated. Musical peaks at the teachers’ ear > 140 dB were assumed to be an artifact (even for “Band”). This seemed to be the case as such peaks were recorded outside of class hours.
- records for which the teachers’ log indicated a departure from the year’s schedule were deleted (e.g. individual student assessments, meeting with Principal, etc.) and not used.

The averaged “refined” PSELs for each teacher are also shown in Figure 3; the group’s standard deviation is lower than that of the “raw” data.

Synthesized L_{EX}

A third method of analysis synthesizes teacher L_{EX} over their timetables using their average $L_{Aeq,T}$ s for each class type (e.g. Band 10) experienced by that given teacher and the duration of that $L_{Aeq,T}$ in the course of their school timetable. The advantage of this method lies in being able to correct for departures from the normal timetable due to low attendance, extra classes, rehearsals etc. and add in extra mural activities, if desired. In addition, where a teacher’s exposure to a given class type was not acquired by dosimetry, an average value for that class type could be substituted from a data bank (Figure 4) built up from the other teachers’ exposure to that class type.

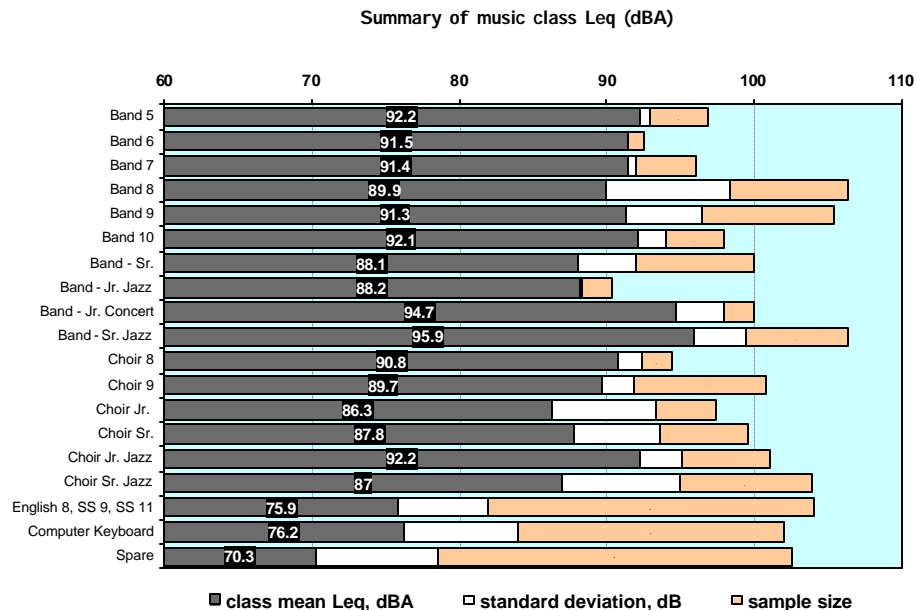


Figure 4. Summary of the School Music Class Database

To convert the calculated daily $L_{Aeq,T}$ to the L_{EX} , two adjustments were applied; to normalize the daily shift to 8 hours (-1.2 to -2 dB) and to normalize the work year from 40 to 50 weeks (-1 dB). The L_{EX} s calculated by synthesizing the exposure from their class schedule for each teacher are also shown in Figure 3.

Noise Exposure Control

The possibilities for reducing the noise exposure of music teachers include:

1. **Reduction of sound power levels.** Sound level reduction at source is practicable through the teacher limiting the percentage of brass instruments in the band and by careful selection of musical pieces. Rehearsal by section rather than in ensemble is encouraged. The use of mutes for brass instruments (whose sound power output is some 10 to 12 dB higher than most other instruments) only seems to be feasible in solo practice sessions.
2. **Hearing protection.** “Conventional” hearing protectors do not have flat frequency responses. This “unbalances” the spectra heard by the wearer and for this reason are unpopular with music teachers. Ear plugs with embedded acoustic filters are available which provide a flat response over a wide frequency band; the plugs still offer very useful amount of attenuation. School Districts offering this type of plug along with training report acceptance by a majority of music teachers (Ref. 7). Some teachers remove the plugs when speaking to individuals. For this reason others have switched to ear canal caps. Relative motion of the headband on clothing can generate noise in the ear interfering with listening. Again, the small amount of attenuation is sufficient.
3. **Room treatment.** Rooms provided for music are often unsuited for this activity. The room may be an ordinary classroom - too small, low and reverberant. The introduction of large areas of highly sound absorbent materials into a music room can have definite but limited sound reducing capabilities. The optimum amount of sound absorption is a matter of achieving a compromise between “liveliness”, “ensemble” and noise reduction. Reverberation times of 0.5 to 0.7s have been suggested as optimum. In many music rooms the acoustical absorption would have to be approximately doubled. Such undertakings would be quite expensive and result in about 3 dB reduction only in the far field where a teacher would spend most time.
4. **Deployment.** Louder instruments are usually deployed to the rear. This is particularly beneficial where room treatment has been added and concentrated over the rear wall and ceiling.
5. **Class size/teaching load.** A theoretical exposure reduction of 3 dB would follow a halving of the class size or number of teaching periods. This approach has the highest cost-benefit ratio.

Conclusions

Peak noise levels are poor indicators of teacher noise exposure. Dosimetry was needed for at least 2 complete and typical days to provide sufficient data to characterize teacher noise exposure. Short-term dosimetry can be misleading too as teachers’ hourly $L_{Aeq,T}$ s can vary over a 15 dB range.

Figure 3 shows good agreement between the different techniques; for the teachers' less frequently sampled, the differences are greater. The process of exposure averaging for an entire synthesized timetable had only slight affect on the average L_{EX} obtained from raw data. The standard deviation in the synthesized approach is reduced considerably and helped reduce the data collection load needed for the target precision. The exposure of the peripatetic teacher can be estimated by this means.

Using Canadian Standard Association's Draft Standard CSA Z107, we concluded for our sample of ten teachers with standard deviation 3.8 dB for the Provincial population of 450 of school music teachers that $L_{EX} = 85.5 \pm 2$ dBA (95% confidence). In the light of the publication of ISO 9612:1997(E) (Ref. 8) we can, using Table D.1, estimate the 90 % confidence limits of the uncertainty due to sampling, u_s , = ± 2.6 dB (90% confidence limit). Table D.2 gives the instrumentation uncertainty, u_i , as ± 1 dB for Type 2 measuring instrumentation used with Type 1 calibrators and u_i as ± 1.5 dB for Type 3 measuring instrumentation used with Type 2 calibrators. This project used Type 2 measuring instrumentation with Type 2 calibrators, so we assume $u_i = 1.25$ dB. The total uncertainty, $\epsilon = \sqrt{u_i^2 + u_s^2}$ or:

$$L_{EX} = 86 \pm 3 \text{ dBA (90\% confidence)}$$

Full time band teachers had a lower L_{EX} than part-time teachers ($L_{EX} = 85.9$ compared to 88.4 dBA). This may be because L_{EX} is more to teacher style and musical selections than to the fraction of time the teacher spends in music. Rooms, numbers of students and their ages (affecting emitted sound power) are factors full and part-time band teachers share in common. Full time choir teachers have exposures almost as high ($L_{EX} = 85.3$ dBA) as band teachers. The part time choir teacher had a low exposure largely due to the small fraction of time in choir classes, perhaps teaching style and selections.

An interesting feature of Figure 1 is the gradual reduction in the $L_{Aeq,T}$ produced by their class with increasing age of Band players. Jazz and concert bands put an end to this encouraging trend. A similar trend is seen in Choir too. The explanation could lie in the improving skill of the musician; as the player acquires skill with their instrument, he/she can play more softly. Another factor, the effects of musical selection and style can have on sound levels, is clearly exemplified by the jazz bands.

The $L_{Aeq,T}$ for English/Socials classes is about 76 dBA. This sound level is largely due to the teacher's own speech and places a noise floor on the teacher's noise exposure.

References

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2. Hetu R. et al, *Problems of noise in school settings, a review of literature and the results of an exploratory study*. J. Speech Lang Pathol Audiol. 1990;14:31-39
3. Workers' Compensation Board of British Columbia "Industrial Health & Safety Regulations", Section 13.21, January 1, 1978

4. ISO 1999(1990) “Acoustics – Determination of occupational noise exposure and estimation of noise-induced hearing impairment”.
5. Bruel & Kjaer, *Instruction Manual Noise Dose Meter Type 4436*, September 1991
6. Canadian Standards Association CSA Z107.56 “Procedures for the Measurement of Occupational Noise Exposure”. The first draft of a proposed new edition (Nov. 1993).
7. School District 41 (Burnaby), B.C., *Hearing Conservation Program*, Revised 02/98
8. ISO 9612(1997(E)) “Acoustics – Guideline for the measurement and assessment of exposure to noise in a working environment”

Appendix

Teacher: FR Date: 931117		Sound levels in 10 minute periods		Sound level over class duration L _{Aeq,T} dBA	Activity from teacher's Daily Log
Time: hh:mm	L _{Aeq,T} dBA	Max. “Peak”, dB			
08:11	95.9	124.7			singing on sound
08:20	92.1	118.6			System,
08:30	90.5	113.8			Piano
08:40	90.8	114			Sr. Jazz Ch
08:50	86.5	118.4	92.2		
09:00	86.1	119.1			Class
09:10	94.3	118.7			discussion,
09:20	87.1	119.7			Vocal
09:30	84.7	110			warm-up,
09:40	88.8	115.5			Singing
09:50	89.3	114.9			Repertoire
10:00	79.4	115.1	89.0		Choir 9
10:00	83.9	117.9			class
10:20	81.8	106.3			discussion,
10:30	84.5	110.9			Vocal
10:40	84.9	114			warm-up,
10:50	89.3	116.6			Singing
11:00	88.5	116.3			Repertoire
11:10	88.6	118	86.7		Choir 9
11:20	82.2	110.7			Class
11:30	80.4	112.2			Discussion
11:40	80.5	112.4			79 students
11:50	75.3	108.7			
12:00	78.8	111.4			
12:10	71.9	106.7			
12:20	81.1	108.3	79.6		Choir 11/12
12:30	76.7	112.6			Lunch
12:40	87.5	120.3			Hour
12:50	79.8	116.8			
13:00	83.2	114.6	83.5		
13:10	75.5	110			Spare
13:20	74.3	107.1			
13:30	72.4	108.4			Meeting

13:40	67.4	100.9		with
13:50	67.5	97		Vice-
14:00	69.9	98.5		Principal
14:10	69.1	107.7	71.9	
14:20	73.6	107.6		late start -
14:30	69.5	107.3		VP meeting
14:40	79.3	116.8		lecture,
14:50	85.7	122.8		Class
15:00	81	113.9		Discussion
15:10	83.3	112.8		
15:20	79	119.7	81.1	comp 11/12
		Duration, T	7.15	hours
		L_{Aeq,T}	83.2	dBA
		L_{EX}	82.7	dBA

Figure 1. Sample of a Day's Sound Level History of a Choir Teacher

A Week's Synthesized Sound Level History of a Choir Teacher

