Methods for assessing safe seniority in high noise conditions

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Abstract A method for estimating the maximum allowable length of service in high noise conditions based on the calculation of the allowable working dose when working in working conditions with exceeding hygienic standards, which is based on the “equal energy” rule applicable to any factor of the each working environment is presented. A method of calculating the dose of the permissible noise level during the entire seniority LCT is proposed, on the assumption of threshold permissible values of the sound level (equivalent sound level), which allows implementing an occupational safety management strategy, both through organizational measures (transfer to areas with acceptable noise levels) and the development of measures to improve working conditions and safety. The dose principle of hygienic rationing allows us to estimate the actual load on the employee's sensory systems and the required number of days of rest or work with reduced noise levels. To solve this problem, in the presented methodology, analytical methods that are proposed, allows to count the number of days of rest (or work with a reduced dose of noise) during a shift, month or year depending on the value of the equivalent noise level LA and the duration of its impact.

Introduction
Analyzing the state of working conditions, which is presented nowadays in the scientific and technical literature, in particular, in published ILO papers [1], we conclude that a trend has emerged to develop an analytical approach in developing solutions for managing improved working conditions and occupational safety. Increased noise at workplaces is one of the major production hazards in most industries. Constant exposure to noise on a worker can cause significant health damage. Modern concepts in labor protection consider noise as a threat to the health and safety of workers in many professions by many criteria. Noise can lead not only to deterioration in hearing, but also is a stress factor, increases systolic blood pressure, reduces concentration and productivity of workers. In addition, noise contributes to the occurrence of accidents, masking warning beeps and interfering with concentration. Noise has a particularly negative effect on intellectual workers.

Noise also has a significant negative combined effect in combination with other harmful production factors, such as low temperature and increased vibration, increases the risk of damage to the health of workers [8,15], contributes to the appearance of hearing loss.

The mechanism for the development of hearing loss under the action of noise of varying intensity is quite complex. At the same time, the primary, insignificant decrease in hearing is further transformed into a permanent, diagnosable, as professional hearing loss. Noise also contributes to a more rapid development of fatigue, which, in turn, leads to a decrease in labor productivity, contributes to an increase in overall morbidity and injury.
As noted in a number of publications [6,16], when working with an increased noise level, starting from \( \geq 87 \text{ dBA} \), the risk of occupational disease is in the range from 1 to 10%, and at \( \geq 105 \text{ dBA} \), the risk of occupational disease is in the range from 30 to 100%.

1. Classification of working conditions in Russia, depending on the level of noise and other factors of the working environment and labor process

In order to determine the number of additional days of vacation, surcharges to the tariff rate, the appointment of a preferential work pension and other benefits and compensations, in case of working in working conditions in excess of national hygienic standards, Russia has introduced a classification of working conditions according to the degree of harmfulness [4].

In particular, Table 1 presents classes of working conditions depending on the levels of acoustic parameters in the workplace. Maximum permissible levels of noise, infra and ultrasound should be determined in accordance with hygienic standards presented in SN 2.2.4 / 2.1.8.562-96 "Noise at workplaces, in residential and public buildings and residential areas" [9] and SanPiN 2.2.4.3359-16 "Sanitary and epidemiological requirements for physical factors at workplaces") [10].

The maximum permissible noise levels at workplaces in Russia were established taking into account the severity and intensity of work activity (SanPiN 2.2.4.3359-16 Sanitary-epidemiological requirements for physical factors at workplaces, Appendix 6).

This means that in order to determine the permissible sound level for noise corresponding to specific working conditions, it is necessary to first conduct a quantitative assessment of the severity and intensity of the work performed by the worker.

Assessment of working conditions when the employee is exposed to constant noise is carried out according to the results of sound level measurement, in dBA, on the scale “A” of the sound level meter on the time characteristic “slowly”.

Note - constant noise - noise, the sound level of which during the work shift varies in time by no more than 5 dBA when measured on the sound level meter's characteristic “slowly”.

| The name of the indicator, unit | Valid 2 | Class of working conditions | Harmful 3.1 | 3.2 | 3.3 | Dangerous 4 |
|--------------------------------|---------|-----------------------------|-------------|-----|-----|------------|
| Noise, equivalent sound level, dBA | \( \leq 80^* \) | >80-85 | >85-95 | >95-105 | >105-115 | >115 |

* Corresponds to SanPiN 2.2.4.3359-16 "Sanitary and epidemiological requirements for physical factors at workplaces" and sanitary norms SN 2.2.4 / 2.1.8.562-96 "Noise at workplaces, in residential, public buildings and residential areas".

When the employee is exposed to inconstant noise, the assessment of working conditions is made based on the results of measuring the equivalent sound level for an 8-hour working day (personal noise dosimeters, integrating sound level meters meeting the requirements of IEC 61252), it is possible to use a calculation method.

If, during a shift, a worker is affected by noise with different temporal characteristics (constant, non-constant — oscillating, intermittent, impulse) and spectral (tonal, broadband) characteristics, in various combinations, as well as depending on the analysis of the working environment, the chosen measurement strategy, measure or, ultimately, calculate the equivalent sound level for the 8 hour shift.

To obtain comparable data in this case, the measured or calculated equivalent sound levels of the pulsed and tonal noise are increased by 5 dBA, after which the result is compared with the remote control without a downward correction set by sanitary norms. [9]

2. Protection by time during the work in the conditions of the noise exceeding hygienic standards

To reduce noise exposure, one of the most effective ways is to introduce regulated breaks, i.e. carrying out organizational measures that promote the rationalization of work and rest schedules in conditions
of exposure to intense noise, as well as the use of personal hearing protection (headphones, antiphones, etc.).

The duration of additional regulated breaks is determined based on the actual sound level, its frequency characteristics, shift period and the presence / absence of personal protective equipment (Table 2). [5].

In cases where, due to security conditions, the use of headphones is not allowed (the need to listen to signals, etc.) only the sound level and its spectrum are taken into account.

**Table 2.** Recommended duration of regulated additional breaks in terms of exposure to noise, min. [5]

| Sound levels (LpA), dBA and equivalent sound levels (LpAeq), dBA | Noise frequency response | Work without anti-noise | Work with anti-noise |
|---------------------------------------------------------------|--------------------------|------------------------|---------------------|
|                                                              |                          | Before lunch break     | After lunch break   | Before lunch break | After lunch break |
| ≥85 - ≤95                                                     | low frequency            | 10                     | 10                  | 5                   | 5                 |
|                                                               | midrange                 | 10                     | 10                  | 10                  | 10                |
|                                                               | high frequency           | 15                     | 15                  | 10                  | 10                |
| >95 ≤105                                                      | low frequency            | 15                     | 15                  | 10                  | 10                |
|                                                               | midrange                 | 20                     | 20                  | 10                  | 10                |
|                                                               | high frequency           | Work is recommended, only with the use of double PPE and a reduced work shift |
| >105 ≤115                                                     | midrange                 | 10                     | 10                  | 15                  | 15                |
|                                                               | high frequency           | 15                     | 15                  | 15                  | 15                |
| >115 ≤125                                                     | midrange                 | 20                     | 20                  | 10                  | 10                |
|                                                               | high frequency           | Work is recommended, only with the use of double PPE and a reduced work shift |

Note - in the case of exposure to pulsed noise, the duration of the regulated break should be the same as for constant noise with a level 10 dBA higher than the pulse. For example, for a pulsed noise of 105 dBA, the duration of interruptions should be the same as with a constant noise of 115 dBA [5].

When conducting regulated breaks, rest should be organized in rooms with optimal microclimatic parameters and low noise levels. Those working during the lunch break, if there was an increased noise level at their workplaces, should also be in optimal acoustic conditions (the sound level should not exceed 50 dBA) [5].

**Table 3.** Relationship between the duration of the noise, its level and the dose of noise (at times from permissible), (Table 2.3) from [11].

| Dose of noise Pa2h, for 8 hours | Allowable duration of exposure to noise during the period of stay in a noisy area of work without a PPE, Equivalent Levels, dBA |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------|
| 0,32                            | 80  83  86  89  92  95  98  101                                                                                     |
| Excess noise (number of times)   | 1   2   4   8   16   32   64   128                                                                                   |
| (not exceeding)                  |                                                              |

Note - in the case of the absence of anti-noise, according to table 3, we see that with noise over 101 dBA, the assignment of additional regulated breaks does not make sense, permissible operating time in such conditions does not exceed 3.5 minutes.

3. The method of calculating the recommended work experience in high noise conditions

The proposed method for calculating the recommended length of service in conditions of increased noise is based on the “equal energy” rule and the principle of dose estimation of noise [6].
The existing methodological recommendations on the dose estimate of production noise [11] allow only the level of the service dose $L_{dn}(T)$ in dB to be determined, for $T$ years worked under conditions of high noise, as well as the required number of working days with reduced noise, which corresponds to an equivalent noise level of 3 dBA below hygienic standards) after performing work for up to 30 days at elevated noise levels compared to hygienic standards. Obtained, according to the methodological recommendations, the indicators are indirect and do not allow with a high accuracy to determine the minimum allowable length of service in conditions of noise exceeding hygienic standards.

The calculation algorithm, according to the proposed method, is as follows:

- first, the permissible dose of sound energy per work shift is determined, according to national hygienic standards - table 4, corresponds to [11].
  \[ D_{pl} = 0.04 \times 8 = 0.32 \text{ (Pa2h)} \] for the work shift;
  where: - 8 is the shift duration; 0.04 Pa2h - permissible sound energy in 1 hour;

- in the future, the permissible total acoustic energy per working month is determined
  \[ D_{pl} (m) = E \times 22 = 7.04 \text{ (Pa2h)} \] – per working month;
  where: - 22 is the average number of working days in a month;

- The next step is to determine the permissible sound energy for the working year.
  \[ D_{pl} (y) = D_{pl} \times 247 = 79.04 \text{ (Pa2h)} \] – for the working year;
  where: - 247 is the average number of working days per year;

- ultimately determine the allowable level of sound energy for the entire working experience
  \[ D_{pl} \text{ (total)} = D_{pl} (y) \times 40 = 3162 \text{ (Pa2h)} \] – for the entire work experience;
  where: 40 is the estimated work experience, years;

The final formula for calculating the recommended work experience in high noise conditions is as follows:

\[
T_1 = \frac{D_{pl} \times E \times N \times Y}{\sum_{i=1}^{n} (D_f \times E_f \times (N - X - \Delta) \times k)}
\]

In the numerator, the maximum permissible dose energy for the entire calculated work experience [3162 (Pa2h)] is calculated, provided that the permissible sound level is 80 dBA in Russia [10], and in the denominator, the sum over the years of work under different noise conditions.

In this case, the actual dose is cumulative, for each year separately. The magnitude of the dose of sound energy for the entire period of actual work experience is calculated taking into account possible changes in the technological process, replacement of equipment (replacement of noisy equipment with low noise in a certain period), transfer of an employee to another workplace, changes in the number of working days in a year, additional leave, etc.

where:
- $T_1$ – calculated experience of permissible work, in excess of hygienic standards, years;
- $D_{pl}$ - maximum allowable level of dose energy per work shift, (0.32 Pa2h);
- $E$ – working time of one shift (8 hours);
- $N$ – the number of work shifts in a calendar year, (~ 247 days);
- $Y$ – the number of years worked (estimated work experience - 40 years);
- $D_f$ - the actual amount of dose energy per shift, Pa2h;
- $E_f$ – the actual time of work in the 8-hour shift (defined as the difference between the 8 hours of the work shift and the total time of the recommended regulated breaks, according to Table 2), hours;
- $X$ – the number of days of basic leave;
- $\Delta$– the number of days of additional leave provided for working conditions in excess of national hygienic standards;
- $k$ – occupational fitness ratio (determined on the basis of the physiological characteristics of the worker and is unique to each person.).
Conclusion

This ratio is determined by health workers, but for this it is necessary that the employee worked in conditions of high noise levels up to 5 years.

Table 4. Relationship between noise exposure levels (dBA) and dose energies (Pa²h), per one hour of operation.

| Application of PPE | Tens of units (dBA) | dBA units |
|--------------------|---------------------|-----------|
| Work without use of protective equipment | 60 | 0.0004 0.0005 0.0006 0.0008 0.001 0.00125 0.0016 0.002 0.0025 0.0032 |
| Recommended Earplugs | 70 | 0.004 0.005 0.0063 0.008 0.01 0.0125 0.016 0.02 0.025 0.032 |
| Required by application headphone | 80 | 0.04 0.05 0.063 0.08 0.1 0.125 0.16 0.2 0.25 0.32 |
| 100 | 4 5 6.3 8 10 12.5 16 20 25 32 |
| 110 | 40 50 63 80 100 125 160 200 250 320 |

An example of calculating the allowable length of service for workers in the machine shop (additional leave for noise is 7 days, with a class of working conditions 3.2; the actual sound level is 87 dBA, the norm is 80 dBA according to СН 2.2.4 / 2.1.8.562-96):

\[
T_1 = \frac{D_{pl} \times E \times N \times Y}{D_f \times E_f \times (N - X - \Delta) \times k} = \frac{3162}{0.2 \times 7.33 \times (247 - 28 - 7) \times 0.9} = 11.3 \text{ years}
\]

Note - the calculations were made when the value of \( k = 0.9 \) (average value is 0.8) and when the permissible sound level is exceeded by 7 dBA. Additional leave, with a class of working conditions of 3.2, is 7 days, and with a class of 3.1, \( \Delta = 0 \). Provided that the employee does not use personal hearing protection.

The results of calculations of work experience in harmful conditions of noise are presented in table 5:

Table 5. Values of the estimated work experience when working in harmful conditions of noise.

| Class working condition (degree of harm) | Exceeding the remote control, dBA | Actual work time for 8 hour work shift with PPE/without PPE, min. (hour), (taking into account the protection of time) | Estimated work experience without the use of PPE(T1) | Estimated work experience taking into account the application of earplugs (-10dBA), (see Table 5) | Estimated work experience taking into account the use of antinoise headphones (headphones, depending on the quality of production, reduce from 10 to 35 dBA, the calculation is made when the earphone drops by 15 dBA) |
|----------------------------------------|---------------------------------|-------------------------------------------------|-----------------------------------|-------------------------------------------------|-------------------------------------------------|
| 3.1                                    | 1                               | 440**/440** (7,33h)                              | ≈40 years                         | 34,7 years                                       | 34,7 years                                       |
| (≥80,5 - ≤85) dBA                     | 2                               |                                                 | 27,4 years                        | 21,9 years                                       | 21,9 years                                       |
|                                        | 3                               |                                                 | 17,5 years                        |                                                 |                                                 |
|                                        | 4                               |                                                 | 14,1 years                        |                                                 |                                                 |
|                                        | 5                               |                                                 | 40 years                          |                                                 |                                                 |
| 3.2                                    | 6                               | 440**/440** (7,33h)                              | 40 years                          |                                                 |                                                 |
Table 6 * The effectiveness of personal protective hearing equipment according to laboratory and field tests.

| Anti-noise groups | Noise reduction efficiency, dB (laboratory data) | Noise reduction efficiency, dB (field data) |
|-------------------|-----------------------------------------------|------------------------------------------|
| Earplugs          | 16-28                                         | 1-12                                     |
| Headphones        | 22-24                                         | 10-14                                    |

* - data taken from [7].

As can be seen from table 4, the values of the estimated work experience when working in hazardous conditions, associated with a significant excess of noise levels, and without the use of PPE, are relatively small. To increase the estimated work experience in these conditions, it is necessary, unequivocally, to increase the number and duration of regulated breaks, and in case of the class of working conditions 3.2 and above, it is necessary to use personal hearing protection.

References
[1] Ilonw.safework.ru. ISBN 978-92-2-419872-4(web pdf).  
[2] Salkutsan V., Mjasnikov V Strategy of labour safety management.  
[3] On approval of the standard list of measures annually implemented by the employer to improve
working conditions and occupational safety and reduce occupational risk levels: Ministry of Health and Social Development of the Russian Federation dated March 1, 2012 No. 181n.

[4] Order of the Ministry of Labor of the Russian Federation dated January 24, 2014 N 33n "On approval of the Methodology for conducting a special assessment of working conditions, Classifier of harmful and (or) occupational hazards, form of a report on conducting a special assessment of working conditions and instructions for filling it out."

[5] Guideline R 2.2.2006-05 “Guidelines for the hygienic assessment of factors of the working environment and the labor process. Criteria and classification of working conditions

[6] Denisov E Dose assessment of noise and vibrations / Occupational health risk for workers. (Guide). - M. : Institute of Occupational Medicine, 2003. - P. 109–114.

[7] Denisov E, Morozova T, Adeninskaya E, Kourier N Occupational medicine and industrial ecology №4 2013. The problem of the real effectiveness of personal protective equipment and the added risk to the health of workers. year 2013

[8] Timofeeva V The duty dose and safe experience // Solution of environmental problems of an industrial region: abstracts of reports of the All-Russian Scientific and Technical Conference // Tula: Innovative Technologies Publishing, 2012. - P. 111–113.

[9] Noise at workplaces, in residential, public buildings and in residential areas. Sanitary standards. SN 2.2.4 / 2.1.8.562-96. – M. : Information and Publishing Center of the Ministry of Health of Russia, 1997.

[10] Sanitary and epidemiological requirements for physical factors in the workplace.

[11] Sanitary-epidemiological rules and regulations of SanPiN 2.2.4.3359-16. – M. : Information and Publishing Center of the Ministry of Health of Russia, 2016.

[12] Guidelines for the dosage assessment of industrial noise № 2908-82. the orders of the Red Banner of Labor of the Research Institute of Occupational Hygiene and Occupational Diseases of the Academy of Medical Sciences of the USSR were developed. Moscow, 1982.

[13] CH 2.2.4 / 2.1.8.583-96 “Infrasound at workplaces, in residential and public buildings and on the territory of residential development. M. : Information and Publishing Center of the Ministry of Health of Russia, 1997.

[14] SanPiN 2.2.4 / 2.1.8.582-96. Hygienic requirements when working with sources of air and contact ultrasound of industrial, medical and domestic purposes. M. : Information and Publishing Center of the Ministry of Health of Russia, 1997.

[15] Braila N V, Khazieva K L & Staritcyna A A 2017Results of technical inspection monitoring of the operation object. Magazine of Civil Engineering, 74(6), 70-77. doi:10.18720/MCE.74.7

[16] Idrisova J I, Myasnikov V N, Uljanov A I & Belina N V 2018 Increasing the efficiency of labor protection in the enterprise. Paper presented at the International Conference on Information Networking, , 2018-January 586-588. doi:10.1109/ICOIN.2018.8343186