Research and increase of efficiency of noise load monitoring and minimization of occupational risks in conditions of industrial noise exposure

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Abstract. The technical means development modern level allows to implement large-scale and continuous approaches to the detection of noise levels affecting the worker. However, IT-technologies of collecting data on working area and residential area noise characteristics, on which basis it is possible to carry out risks prognostic assessments of noise exposure to humans without limitation to the working conditions, industrial control and environmental monitoring special assessment results, are underdeveloped. The research purpose is to assess the collecting data possibility on the noise levels distribution within the working area, residential area and the high levels occupational risk areas determining possibility by the industrial noise factor by means of smart phones. A method was developed for collecting data on the noise levels distribution within the working area, residential area, on which basis a software product for recording and processing data on the noise nature was developed. The industrial noise levels spatial distribution constructing possibility on the construction site in real time as a result of using a special software product was shown. The metadata continuous collection on the noise nature makes it possible to clarify the occupational risks levels associated with noise exposure and to select measures to manage these risks.

1. Introduction and Background
Urbanization and intensification of technological processes in almost all spheres of the economy actualize the industrial noise negative impact problem as a occupational disease source and the main stimulus that increases the psycho-emotional stress level [1].

The industrial noise negative impact assessment in Russian Federation is currently carried out within the working conditions and industrial control special assessment framework. Changing the maximum permissible equivalent noise level to 85 dBA with mandatory measures to protect workers from noise increases the risks of negative noise in the residential area [2-4].

The technical means development modern level allows to implement large-scale and continuous approaches to the detection of noise levels affecting the worker [5-7]. However, IT-technologies of collecting data on working area and residential area noise characteristics, on which basis it is possible to carry out risks prognostic assessments of noise exposure to humans without limitation to the working conditions, industrial control and environmental monitoring special assessment results, are underdeveloped.
The need to assess the industrial noise impact, as well as determine the acoustic environment pollution degree in the residential area continuously, throughout the day and regardless of whether the workplace is permanent or non-permanent is the ability to develop and implement the most effective organizational, architectural and technical measures, taking into account the noise not limited by work shift[8-10].

One of the ways to collect data on the noise nature both in the workplace and in the residential area, followed by collected empirical data calculated values assessment on noise levels directly in the workplace and to make a comparative assessment with the measured data, is the use of mobile devices, or devices based on them.

Currently, software products carrying out the registration of noise levels, sound transmission and its characteristics from the smart phone to the computer and vice versa are known on the software products market sold on the operating systems basis for smart phones.

Therefore, the study purpose is to assess the collecting data possibility on the noise levels distribution within the working area, residential area and the occupational risk high levels zones determining possibility by the industrial noise factor for the subsequent selection of the most effective way to prevent the negative industrial noise impact.

2. Materials and Methods
The continuous data collection technique on noise levels at working area different points can be implemented in at least two basic ways:
  - permanently installed subsystems, including a microphone and a device for transmitting audio signals;
  - subsystems assigned to each employee and implementing continuous recording of noise levels that affect it and their transfer to the server, which in turn processes the data.

The second direction, combined with obtaining data on the GPS transmitter position coordinates associated with the employee, will also allow determining the noise pattern levels spatial change for a single employee both within the working area and in the residential area.

The used computational algorithm is as follows:
  1) IP address of the device that will register the noise is set;
  2) receiving and processing of audio signals from the device on the PC acting as the server is carried out;
  3) the octave sound pressure levels, dB, and equivalent noise levels, dBA at each point where the worker is are determined;
  4) the sound field is calculated in octaves.

The algorithm for processing the results obtained from smart phones was automated in the MVS environment in C# language using the freely distributed NAudio library. The registration itself and preparation for the information transmission about the noise environment state was carried out on the Android operating system basis in the Kodian programming language. This algorithm can be used to estimate the noise dose received by the employee during the work shift and in the residential area and to determine the high noise level areas that require the priority measures introduction to protect against noise.

3. Experimental Section
One of the proposed algorithm implementation problems is the results reliability the, which depends on the user's smart phone microphone. It should produce results that are well correlated with the verified noise measuring instruments results.

The tonal sound comparative measurements at the frequency of 500 Hz and 1000 Hz in the reverberation chamber by integrating sound level meter "AssistentTotal" and by smartphone with installed software, performing current noise registration were conducted. The smart phone microphone spectral characteristics in the tonal noise perception and the sound pressure levels values of the same sound signal in octaves measured by the integrating sound level meter are shown in figures 1, 2.
Figure 1. Sound levels at a frequency 500 Hz.

Figure 2. Sound levels at a frequency 1000 Hz.

The reinforced concrete structures installer working process on the construction site was considered and continuous in time equivalent noise levels registration affecting the installer was considered. Thus its spatial position on a building site during all time of carrying out measurements was fixed. Figure 3 shows the installers routes within the construction site who used the mobile application and through which noise levels were recorded. Registration of routes was carried out by installers. The experiment participants used the same smartphone model.
4. Results and Discussion

As a result, octave noise levels arrays and equivalent noise levels were obtained on the installers routes, which were recorded by the microphones of smartphones. Figure 4 shows the change in the equivalent noise level during the 60-minute exposure of the installer.

The maximum, minimum equivalent noise level values and noise levels at frequencies of 500, 1000 Hz were (table 1):

| Noiselevels | 500 Hz | 1000 Hz | Equivalent noise level, dBA |
|-------------|--------|---------|----------------------------|
| Maximum     | 49,7   | 39,9    | 95,2                       |
| Minimum     | 10     | 2       | 55,4                       |
Figure 5 shows the possible noise levels distributions field at the frequency of 500Hz. The fields construction was carried out according to the following algorithm – the measurement points falling into the same noise levels range were connected to each other by lines, while the lines connecting the points to the noise levels of another range should not intersect with the other ranges segments.

As a result of the continuous noise recording system using at the operating system location, the following values of noise levels in octaves were recorded (see fig. 5) in different working area parts. Obtained data processing allowed to determine the actual equivalent noise level, which was 89 dBA. That is less than the theoretically predicted values, and accordingly, allows for a more cost-effective, but not less effective personal hearing protection choice.

The proposed approach makes it possible to obtain more complete data on the noise nature in the workplace compared to the existing noise measurement method in the framework of a working conditions special assessment and industrial control, which regulates the measurement carrying out depending on the noise nature that is not more than 30 minutes long.

It follows from fig. 5 that to build a noise distribution spatial picture quite a large participants number is necessary, which will cover almost the working area entire space, in case of their paucity, stationary recorders can be used. However, the proposed approach gives satisfactory results for the noise impact assessment case on the installer and its dose determination.

One of the significant drawbacks approach proposed is the hardware data obtained reliability ensuring complexity from different users with different microphones sensitivity characteristics. To minimize this error, a large number of observations in the same residential area points with their subsequent statistical processing are necessary.

5. Summary and Conclusion

The measurement results analysis showed satisfactory convergence in the middle frequency range. As for high and low frequencies, it is necessary to correct the measurement results obtained from the smartphone.

The multiple data collection implementation on noise levels allows to build a noise negative impact risks fields on workers throughout the work shift and to manage these risks for different time periods,
and as soon as the employee gains a critical noise dose, transfer it to working area spaces with lower noise levels, along with developing measures to normalize noise levels in greatest risk areas.

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