CHAPTER

3.3 Active monitoring technology in studying the interaction of geophysical fields

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Chapter Outline

3.3.1 Introduction

The problem of predicting the geoecological effect of various technogenic explosions, namely, short-delay quarry blasts (Adushkin, 1996; Adushkin et al., 2000), test site blasts (Khairetdinov and Avrorov, 2012), explosion of carrier rocket, down through the atmosphere etc., on the natural environment and social infrastructure is of primary importance. Mass explosions that have been made recently for the purpose of eliminating the utilizable ammunition stock are a serious hazard. Powerful natural explosions include, first of all, eruptions of magmatic and mud volcanoes (Laverov, 2005) and falls of celestial bodies. It is well-known that the major geoecological effects of explosions are due to the

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formation of air-shock and underground seismic waves, and the formation and propagation of dust clouds and electric pulses. Investigation of the seismic and acoustic effects of mass explosions damaging industrial and residential objects and the shock action on bio-objects is of greatest interest. Nevertheless, it should be noted that the dependence of these effects on external factors, such as wind direction and strength, temperature inversion, atmospheric turbulence, and the surrounding area relief and landscape, has been poorly studied. This is all the more important since the influence of such factors can greatly enhance the destructive ecological action of explosions on the environment. Taking into account the above factors, it is necessary to predict the geoecological risk of powerful explosions, which calls for additional investigations into the physical effects of the propagation of seismic and acoustic waves from mass explosions. The objective of this chapter is to present a methodological approach to carrying out such investigations and obtaining experimental and numerical results. The approach proposed is based on seismic vibrators as sources imitating explosions, but having, in contrast, much less power. In this case, as compared to explosions, ecological cleanness and repeatability of experiments are achieved. This is due to the high-precision power and frequency-temporal characteristics of vibrational sources (Alekseev et al., 2004). The approach proposed for prediction with seismic vibrators was used because of the ability of vibrators to simultaneously generate both seismic and acoustic oscillations. This was proved earlier both theoretically and in numerous experiments for this class of sources (Alekseev et al., 2004).

3.3.2 Problem statement

As an integral characteristic in studying the destructive properties of infrasound from explosions for the environment, we take the specific acoustic energy density:

$$E = \frac{1}{\rho \ c} \int_0^T p^2(t) \ dt. \tag{3.3.1}$$

where $\rho \ c$ is a specific acoustic air resistance of 42 g/(cm^2 s); $p(t)$ is the acoustic pressure recorded at the acoustic sensor output; and T is the acoustic wave duration. The wave pulse energy value is calculated using experimentally obtained records. Admissible acoustic effects on objects of social infrastructure are determined by the specific energy density values in J/m^2. In Eq. (3.3.1) acoustic pressure is a function of many parameters determined by the radiation conditions and the propagation of acoustic oscillations.

The multifactor model of integral pressure can be described by the energy balance equation:

$$P_{\Sigma}(t, f, r) = P_v(f) + P_1(r) + P_2(e, t_{air}, w_0, \varphi) + P_3\left(\frac{1}{r}\right) \tag{3.3.2}$$

where $P_\Sigma(t,f,r)$ is the pressure at the recording point at distance r from the source; $P_v(f)$ is the frequency-dependent acoustic pressure of the vibrator; $P_1(r)$ is the absorption of infrasound depending on the distance determined by the inhomogeneity of the atmosphere and the state of the Earth's daily surface; $P_2(e, t_{air}, w_0, \varphi)$ is the pressure at the recording point as a function of meteorological parameters: relative humidity e, temperature t_{air}, wind speed $w_0.\phi$ is the angle between the wind direction and wave front from the source; $P_3(1/r)$ is the pressure resulting from the spherical divergence of the wave front.

Obtaining the estimates in Eq. (3.3.2) in analytical form is difficult, since there are no full a priori data about the meteorological conditions along the long propagation path of acoustic oscillations. There are also factors due to the peculiarities of absorption of the energy of acoustic oscillations caused by the presence of forested areas, snow cover, and geological irregularities of the Earth's daily surface (hills, mountains, etc.) along the long propagation path of acoustic oscillations.

One way to avoid prior uncertainty is obtaining the estimates in Eq. (3.3.2) in experiments with seismic vibrators as emitters of infralow-frequency acoustic oscillations. Both (analytical and experimental) variants are considered in this chapter.

3.3.3 Acoustic oscillations of seismic vibrators

The experimental approach being proposed is justified by the fact that seismic vibrators can emit both seismic and acoustic oscillations. The total power of infrasonic radiation into the atmosphere, W^a, can be estimated for the case when the acoustic wave speed, c_a, is equal to the transverse seismic wave speed, v_s, that is, $c_a = v_s$, and the longitudinal wave speed $v_p = \sqrt{3} \cdot v_s$. In this case the power of acoustic radiation into the atmosphere is (Zaslavskii, 2007):

$$W^a = \frac{3.16 \cdot \rho_a F^2 \omega^2}{\pi \rho^2 {v_p}^3}.$$

where ρ_a, ρ are the densities of the air and the underlying medium under the vibrator, respectively; F is the perturbing force of the vibrator, ω is the radiation frequency, and v_p is the longitudinal wave speed.

The seismic radiation power is (Zaslavskii, 2007):

$$W^p = 0.085 \frac{F^2 \omega^2}{\pi \rho {v_p}^3}.$$

It follows from the above relations that $W^a/W^p \sim 0.02$. So for example, if $F = 100$ t, $f = 10$ Hz, $\rho_a = 1$ kg/m^3, $\rho = 2000$ kg/m^3, $c_a = 340$ m/s, $v_p = \sqrt{3}c_a = 590$ m/s, when $W^p = 1500$ wt, $W^a = 30$ wt.

Despite the considerable difference in the relation of radiated powers, acoustic oscillations from the vibrator under certain meteorological conditions can propagate and be recorded at considerable distances from the source (Alekseev et al., 1996; Glinskii et al., 1999).

This has become possible thanks to a combination of some favorable physical factors:

1. Acoustic waves in the atmosphere attenuate to a lesser degree in comparison to seismic waves in the Earth having greater geological structure inhomogeneity. On the other hand, high metrological characteristics of radiation of vibrational oscillations open up possibilities of their synchronous accumulation on the background of noise, in particular, by cross-correlation convolution methods (Alekseev et al., 2004).
2. Surface distant propagation of acoustic waves is due to:
   a. The meteorological dependence causing an essential increase in the acoustic pressure at the coincidence of the directions of propagation of the acoustic wave front and wind;
   b. The phenomenon of temperature inversion associated with the formation of a low-temperature layer of air at the Earth's surface at the transition from cold night to warm day;
3. The phenomenon of reflection of acoustic waves from the upper atmosphere.

We now consider these listed factors in more detail.

An illustration of the statement 1 is given in Fig. 3.3.1 which represents the results of simultaneous detection of seismic and acoustic waves by means of

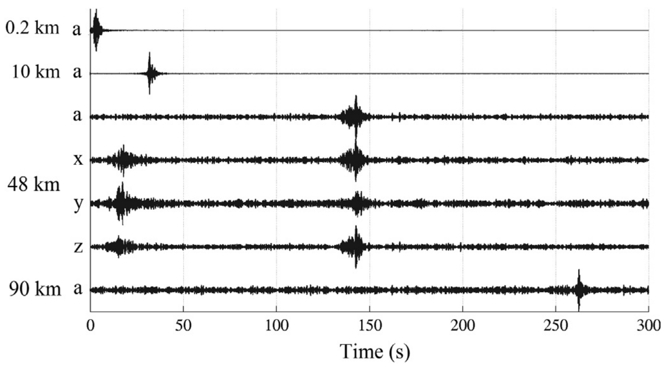

FIGURE 3.3.1

Results of experiments on the detection of waves from the seismic CV-40 vibrator at distances of 0.2, 10, 48, and 90 km: acoustic waves; at a distance of 48 km for the *x*, *y*, and *z* components of the seismic sensor a time of 8.27 seconds corresponds to the arrivals of longitudinal seismic waves, and a time of 146 seconds to the arrivals of acoustic waves.

FIGURE 3.3.2

Seismic CV-40 vibrator.

cross-correlation convolution of long seismic and acoustic oscillations from the centrifugal-type CV-40 vibrator. Sounding signals of the source are described as signals with linear frequency modulation in a frequency band of 6.25−9.57 Hz with a duration of 2850 seconds.

An external view of the CV-40 source radiating such oscillations is shown in Fig. 3.3.2.

In the convolution, a signal whose shape is the same as that of the sounding signal from the vibrator described above is used as a reference signal. Fig. 3.3.1 shows the results of convolution for distances of 0.2, 10, 48, and 90 km. Distances are marked at the left of the figure. At distances of 0.2, 10, and 90 km one can see the results of detection of acoustic waves. At a distance of 48 km the channels of the three-component x, y, z seismic sensor at a time of 8.27 seconds illustrate the arrivals of longitudinal seismic waves, and a time of 146 seconds, the arrivals of acoustic waves. It follows from a comparison of the results of detection of both types of waves that, according to a noise-immunity criterion, the detection of acoustic waves from the vibrator is as good as that of seismic waves.

To illustrate the capabilities of reliable recording of acoustic waves at large distances from the source (the statement 3), Fig. 3.3.3 presents calculated height profiles of propagation of acoustic oscillations in the atmosphere taking into account the phenomenon of refraction of infrasound at specified height profiles of the temperature and horizontal wind. Fig. 3.3.3 shows typical calculated trajectories of infrasonic waves (Gulyev et al., 2001), where one can see that trajectories of acoustic waves can cover a linear profile on the Earth's surface of up to 90 km. This explains why weak acoustic waves can be recorded at large distances.

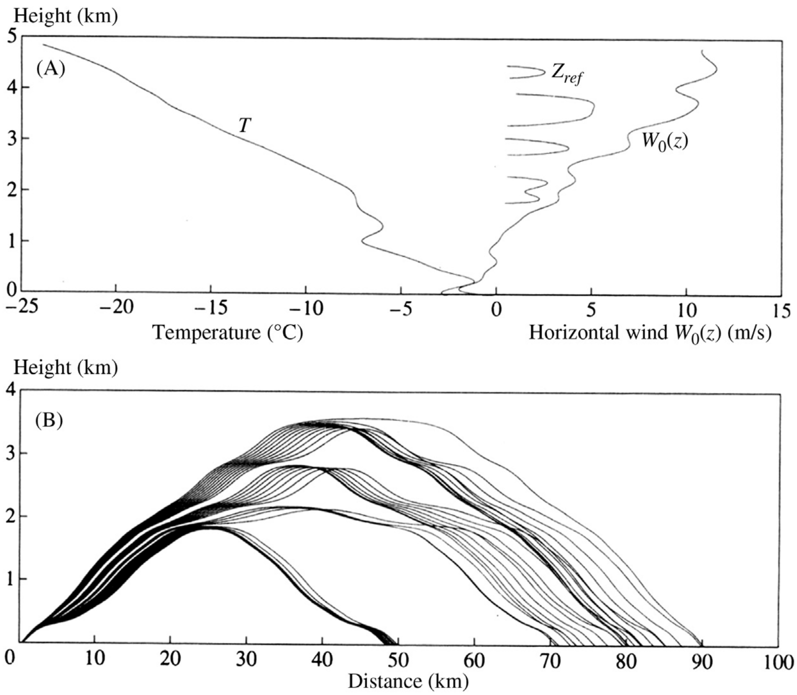

FIGURE 3.3.3

(A) Altitude (in km) air temperature profiles T, component of horizontal wind w_0 (z) m/s according to radiosonde data (summer time), height reflections z_{ref}, (B) calculated height profiles of infrasonic waves.

Based on the experimental data, Fig. 3.3.4 shows, on a logarithmic scale, normalized values of the levels of acoustic and seismic waves and noise obtained at individual recording points.

The plots of wave levels have been normalized with respect to levels obtained at a distance of 200 m from the vibrator. It follows from the experimental data that the averaged weakening of the sound intensity, I, within 100 km is by four orders of magnitude, that is, $D = 40$ dB. Hence, the relative attenuation is 0.4 dB/km. Taking into account the fact that due to geometrical divergence the sound intensity decreases in inverse proportion to the squared distance from the source [in this case by a factor of 100^2 (40 dB)], we can conclude that at infralow frequencies sound attenuation with distance is practically completely determined by this factor. This means that the factor of absorption of acoustic energy in the atmosphere can be neglected. This shows the importance of using infralow frequencies for solving some practical problems of geophysical monitoring, in particular, in

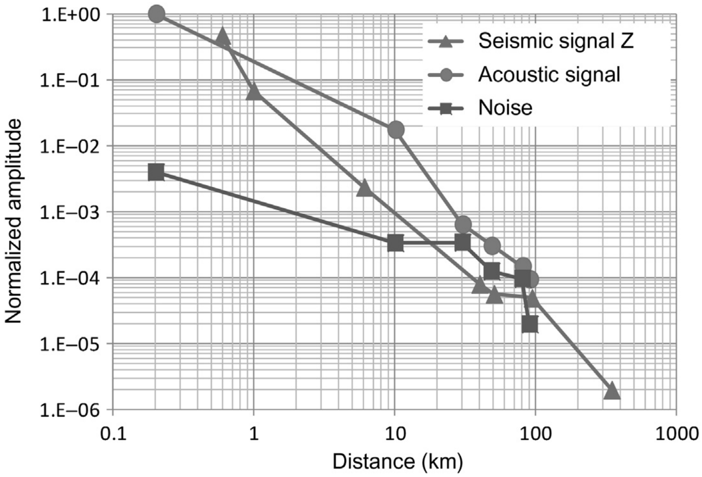

FIGURE 3.3.4

Plots of attenuation of seismic and acoustic waves with distance.

studying the problem of interaction of geophysical fields being considered in this chapter.

3.3.4 Informative factors of interaction of geophysical fields

The effect of meteorological conditions on the propagation of infrasound generated by seismic CV-40 and CV-100 vibrators is considered here. Specifically, under the influence of wind the phenomenon of space focusing of acoustic oscillations takes place, in which the maximum acoustic pressure, p, is achieved when the directions of the propagation fronts of oscillations from the vibrator and of the wind coincide.

Numerical calculations were carried out to estimate the effects of the directivity of the acoustic wave field of infralow frequency sources in a moving medium, that is, on the background of wind characterized by direction and velocity. A point source of infrasound located at a height h over the Earth's surface was considered in the model. The Earth's surface was assumed to be flat and the atmosphere was taken to be layered and inhomogeneous.

The sound and the wind speeds depended only on the vertical coordinate, and the wind speed had only horizontal components. At infralow frequencies, the ray approximation of sound propagation holds, and the sound intensity variation is based on the assumption of geometrical beam divergence. In a rectangular system of coordinates, the z-axis is pointing up from the Earth's surface, and the direction of the x-axis at a height h coincides with the wind direction. The initial direction of the ray is characterized by the spherical θ (zenith angle) and φ (azimuthal angle). The latter is measured from the direction x, which corresponds to the wind direction.

The effect of acoustic field directivity is characterized by the focusing factor (Brekhovskikh, 1973; Razin, 1982), which is the ratio between the infrasound intensity in an inhomogeneous moving medium and its intensity in a motionless medium:

$$f = \frac{I[z, \theta, \varphi]}{I_0}. \tag{3.3.3}$$

where $I(z, \theta, \varphi) = \left(W^a c_0^2 \xi / 4\pi\, c^4 t^2 \cos\theta\right) \times \left[1 + 2\left(w_0/c_0\right)\sin\theta\cos\varphi - 2\eta\right]$; $I_0 = W^a / 4\pi[x^2 + y^2 + (z-h)^2]$; W^a is the source power.

The equation for the focusing factor has the following form:

$$f = \frac{c_0^2 \xi\left[x^2 + y^2 + (z-h)^2\right]}{c^4 t^2 \cos\theta}\left[1 + 2\left(\frac{w_0}{c_0}\right)\sin\theta\cos\varphi - 2\eta\right], \tag{3.3.4}$$

where c is the speed of sound in the motionless medium, $c_0 = c(h)$ is the ray velocity modulus, w_0 is the wind speed along the x-axis, and t is the time of sound propagation along the ray. Expressions for ξ and η are as follows:

$$\xi = \left[1 - \left(\frac{c}{c_0}\right)^2 \sin^2\theta - 2\eta + 2\left(\frac{w_0}{c_0}\right)\left(\frac{c}{c_0}\right)^2 \sin\theta\cos\varphi\right]^{1/2},$$

where $\eta = \left(1/c_0\right)\sin\theta\left(w_x\cos\varphi + w_y\sin\varphi\right)$.

The effect of spatial focusing is considered below for the case of direct surface propagation of an acoustic wave within the first tens of kilometers. The considered case of direct wave propagation corresponds to the theoretically calculated altitude profiles of infrasonic wave propagation, shown in Fig. 3.3.3. Such a review is carried out in order to compare the results of field and numerical experiments. Fig. 3.3.5 shows calculated and experimental curves for the focusing factor versus the observation point azimuth. Here the results of the numerical calculations are presented in the form of continuous plots for specified speeds of 4 and 6 m/s, and the result of the natural experiment, in the form of a dashed curve for a wind velocity of 4–6 m/s. In both cases the source height is 5 m, and the radius of the circular arrangement of sensors is 12 km.

3.3.5 An experimental study of a meteorological-dependent effect of propagation of acoustic oscillations from seismic vibrators

As an acoustic wave propagates in the surface layer of the atmosphere, a surface seismic wave is induced in the Earth, which propagates synchronously with the

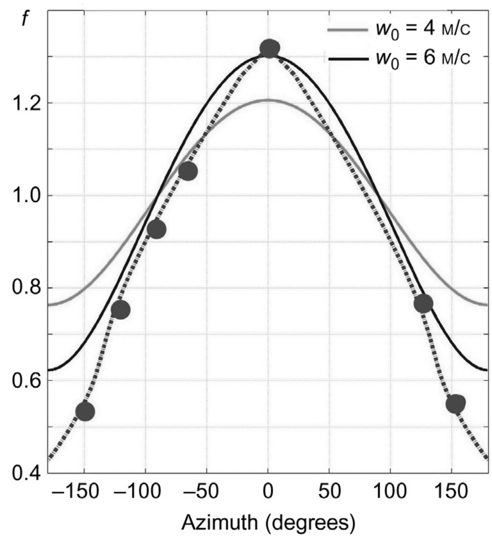

FIGURE 3.3.5

Focusing factor versus observation point azimuth: results of numerical simulation—curves with shown velocities. Source height: 5 m; result of experiments—dashed curves: for a radius of 12 km and a wind velocity of 4–6 m/s.

acoustic wave in the atmosphere. This phenomenon is called acoustoseismic induction (Alekseev et al., 1996). In this case, the velocities of both wave types are the same and equal to the infrasound propagation speed. This wave excites in the Earth a surface seismic wave recorded by seismic sensors. This wave is called an acoustoseismic wave.

To estimate the quantitative effects of wind on the propagation of acoustic oscillations at the vibroseismic Bystrovka test site (Novosibirsk), a number of autonomous seismic stations "Baikal" were installed. The stations were arranged in a circle with a radius of 6 or 12 km, with the CV-40 vibrator at the center. This source has a perturbing force of 40 tf in an operating frequency range of 6–12 Hz. A scheme of sensor arrangement at points 1–7 of the circle is presented in Fig. 3.3.6. The figure shows the possibilities for simultaneous recording by seismic sensors of seismic and acoustic waves from the seismic vibrator.

This figure presents, as the results of recording and processing, vibrational correlograms obtained by the correlation convolution between the reference signal, whose shape is the same as that of the sounding signal, and the recorded initial signal (Gubarev et al., 2014; Khairetdinov et al., 2016). The obtained vibrational correlograms are analogs of pulsed seismograms from the explosions. They illustrate the seismic wave arrivals (waves of the first arrivals) at times of 0.96–1.05 seconds and the acoustic wave arrivals (secondary waves) at times of 16–19.5 seconds. The latter are the waves recorded by seismic sensors as a result

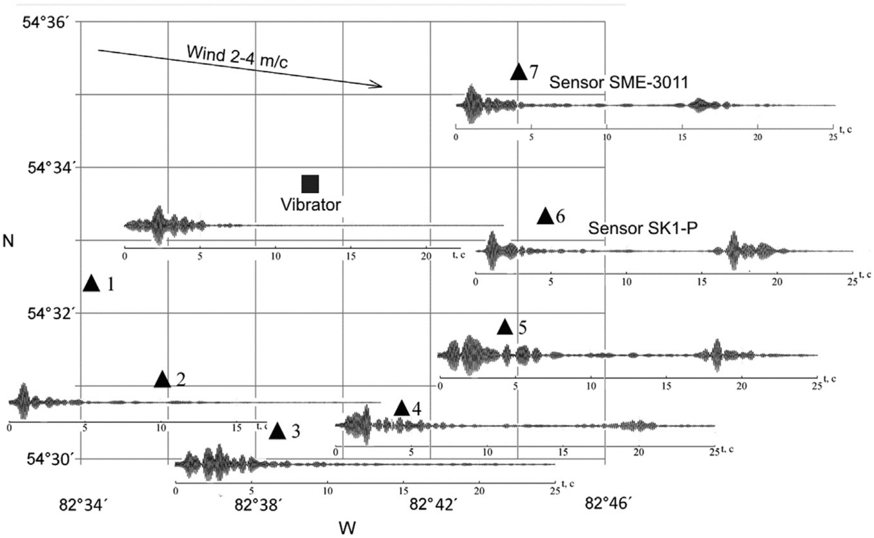

FIGURE 3.3.6

Arrangement of seismic stations "Baikal" with three-component seismic sensors SK-1P and SME-3011 located in a circle with a radius of 6 km. Vibrational correlograms illustrate the arrivals of seismic and acoustic waves. The wind direction is shown by an arrow.

of the abovementioned phenomenon of acoustoseismic induction. These waves are acoustoseismic. It follows from Fig. 3.3.6 that acoustoseismic waves are well-defined in seismograms if the directions of the wind and of the acoustic wave propagation front coincide. In this figure, an arrow indicates the wind direction and velocity (2–4 m/s in this case). In acoustic wave propagation is known in acoustics as the phenomenon of an increase in the efficient sound speed and a decrease in attenuation at the tail wind (Isakovich, 1973).

This reveals the role of meteorological conditions at long-distance propagation of acoustic waves. In the experiments with a vibrator, the detected effect of directivity of the acoustic wave field can be quantitatively estimated when seismic sensors have a circular arrangement.

Wave field directivity diagrams (DD) corresponding to this effect within azimuths of −180 to +180 degrees for the above arrangements are shown in Fig. 3.3.7, curve 1. Here the zero azimuth corresponds to the wind direction. The acoustic pressure values (in Pa) corresponding to the azimuth directions are presented along the vertical axis.

Quantitatively, the directivity effect can be characterized by the DD width in degrees at a level of 0.7 from a maximum value. It follows from the figure that in the case of a circular arrangement radius of 6 km the DD width is 60 degrees. Curve 1 in Fig. 3.3.7 shows a clear dependence of acoustic pressure on wind, for which the ratio between the maximal and minimal acoustic pressure values

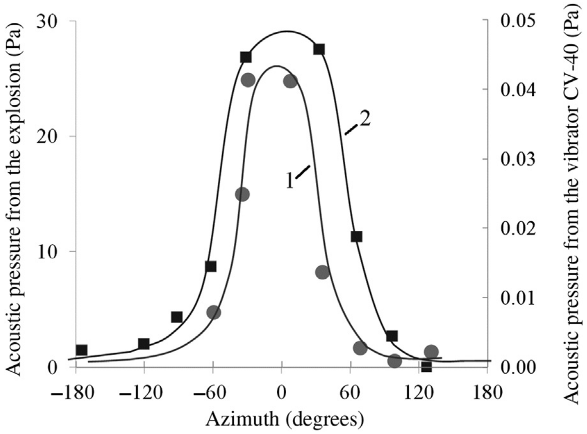

FIGURE 3.3.7

Azimuthal dependence of acoustic pressure for a circular arrangement of sensors and the source at the center of the circle: for the CV-40 vibrator and a circle radius of 6 km (curve 1), for an explosion with a TNT equivalent of 125 kg and a circle radius of 10 km (curve 2)

reaches 50. This acoustic pressure redistribution in space leads to an important conclusion that even low-power explosions can be ecologically dangerous because of a great energy flow increase in a certain direction.

By analogy with the experiments with the vibrator, the wind dependence of acoustic pressure on another source having a direct destructive action on the environment, namely, the test site explosions of utilizable ammunition stock, was studied (Fig. 3.3.7). Seismoacoustic oscillations from explosions are regularly recorded using seismic sensors. For the experimental conditions in Fig. 3.3.7, curve 2 shows the acoustic pressure versus azimuth within −180 to +180 degrees with a wind speed of about 1 m/s.

By analogy with vibroseismoacoustic waves, it also shows a well-defined "wind-dependent" effect of the directed acoustic wave field propagation. A DD width of 80 degrees corresponds to the dependence obtained. The results of experiments on detecting meteo-dependent acoustic effects make it possible to describe them using the directivity function $f(\theta)$, which can be determined by an amplitude rise of acoustic waves within a given angle sector. In this case, it can be said that we have the focusing effect of acoustoseismic oscillations in space. On the sensors arranged in a circle of 10 km in radius, the ratio between the maximum and minimum explosion pressures at a wind speed of 1 m/s vary within a factor of 20.

We now compare the acoustic pressure levels of a vibrator and a test site explosion. The maximal acoustic pressure of the CV-40 vibrator at a distance of 12 km was 0.03 Pa, whereas that of an explosion at a distance of 10 km was almost 30 Pa. Thus at comparable distances from the vibrator the acoustic pressure value is three orders of magnitude less than that of the explosion. This proves that vibrators as instruments for experimental investigations are ecologically clean.

The dependences of pressure on other meteorological parameters (temperature, air humidity) can be obtained from the generalized expression of the equation of gas state $f(p,\rho,t)=0$ relating the pressure, density, and air temperature (Isakovich, 1973). It follows from the definition of sound speed in the air according to Laplace, $c_L=\sqrt{\gamma\cdot(p/\rho)}$, that the pressure $p=(\rho/\gamma)c_L^2$, where $\gamma=c_P/c_V$, there exists a relation between the thermal capacity of air at constant pressure, c_p, to the thermal capacity of air at constant volume, c_v. The pressure is a square-law function of sound speed depending, in turn, on the air temperature and humidity. Thus for an unperturbed atmosphere the sound speed in damp air is $c_O=20.1\sqrt{T(1+0.273(e/p))}$, where e is the air humidity, $T=t+T_O$, $T_O=273$ K. In case of wind with speed w_0, the total speed of infrasound is $c=c_0+w_0\cos\varphi$, where φ is the angle between the directions of the wind and acoustic wave. Taking into account the above meteofactors, the integrated dependence of pressure P_2 (e, t_{air}, w_0, φ) in Eq. (3.3.2) on these factors can be as follows:

$$p=\frac{\rho}{\gamma}(331+0.6t_{air}+0.07e+w_0\cos\varphi)^2. \tag{3.3.5}$$

Apparently, pressure increases with increasing temperature and humidity of the air, and also wind in accordance to the square law.

To record the phenomenon of temperature inversion, experiments with the use of seismic vibrators—the hydraulic resonance vibrator HRV-50 and the centrifugal CV-40 vibrator—have been carried out. Sounding in night and morning hours by seismic and acoustic oscillations in a range of frequencies of 3−7 Hz and at a distance of 20 km has been performed. The final result of this experiment is presented in Fig. 3.3.8. Here the recorded seismic waves on components Z, X with arrival times of 4−6 seconds and an acoustic wave at 60 seconds are given. The date and times are on the left. The records show that an acoustic wave appears at the transition from night to day (in this case the time is 6 hours 55 minutes). Thus the phenomenon of temperature inversion in the ground layer of air is well pronounced.

The influence of air humidity on the levels of acoustic oscillations was estimated in a series of experiments with the CV-40 vibrator at a distance of 50 km. The range of frequencies of sounding oscillations in this case is 6.25−11.23 Hz. Fig. 3.3.9 represents a set of acoustic pressure versus humidity, measured at the same registration point. Humidity is measured using a meteorological station located approximately in the middle of the acoustic wave propagation line from the vibrator CV-40 to the registration point. Measurements are performed individually for each sensing session.

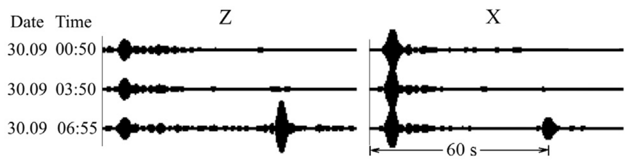

FIGURE 3.3.8

Records of waves during night and morning time from vibrator HRV-50 on removal of 20 km. First arrival of waves with times 4–6 seconds correspond to seismic waves, second waves on 60 seconds to acoustic wave.

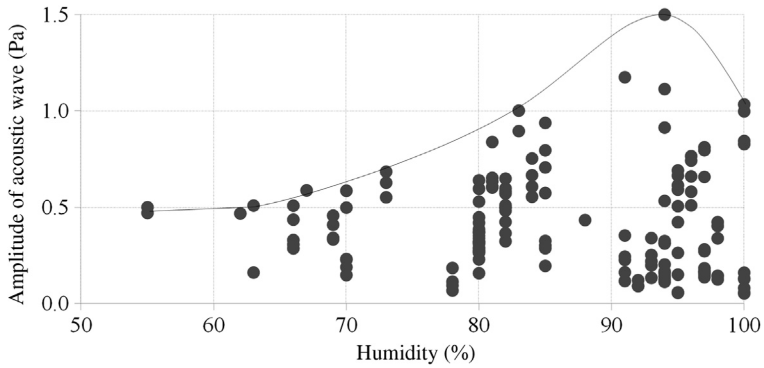

FIGURE 3.3.9

Levels of acoustic oscillations of CV-40 vibrator at a distance of 50 km versus air humidity.

The curve of maximum values shows the regularity of the dependence on humidity. In similar meteorological conditions an increase in humidity of up to 95% can lead to an up to threefold increase in acoustic pressure. Over 95% decrease in acoustic pressure is observed. This can be due to additional strong scattering of air droplets in the air with increasing density.

3.3.6 Geoecological risk of explosions

The geoecological risks for the environment of test explosions with a Trinitrotoluene (TNT) equivalent of 125 kg have been experimentally estimated according to Eq. (3.3.1). Estimates of the specific density of acoustic energy [Eq. (3.3.1)] at distances of 0.45 and 10 km from the explosion have been obtained. The measurement data have been compared with the critical norms for various objects. As an example, Fig. 3.3.10 shows the specific energy values of explosions versus critical (admissible) ones for various objects. Column numbers 1–4 are object types, and 5–6 are specific energy values of explosions at distances of 0.5 and

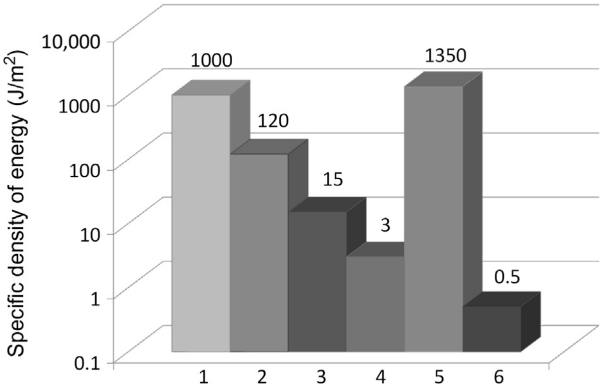

FIGURE 3.3.10

Critical specific energy values for constructions: (1) residential building at a single explosion; (2) residential building at several explosions; (3) 2–3 mm thick window glass; (4) for humans. Explosion energy values: (5) at a distance of 0.5 km from explosion; (6) at a distance of 10 km from explosion.

10 km, respectively. The admissible and measured specific energy values are given above each column. This figure shows the hazard levels of explosions of such power for various types of objects. One can see that an explosion with a TNT equivalent of 125 kg is destructive for buildings; it is even more dangerous for humans, since the admissible norm is exceeded about 400 times.

3.3.7 Discussion

The problem of studying the interaction of various geophysical (seismic, acoustic, meteorological) fields is both of fundamental scientific and practical value. In this chapter, the practical aspect of the problem in the context of prediction of geoecological risks generated by technogenic and natural explosions has been considered. In general estimation of the risks, it is associated with the solution of a multifactor problem of acoustic wave propagation under the influence of the following meteofactors: air temperature and humidity, wind direction and speed, as well as the factors taking into account the state of the Earth daily surface: snow and vegetation cover, its geological heterogeneity, the presence of a water surface, etc.

The original vibration method of sounding of "lithosphere–atmosphere" media by infralow frequency oscillations from seismic vibrators proposed by the authors allows one to estimate the contribution of various factors into the integrated characteristic of geoecological risks for natural and social environments. First of all, it involves meteo-dependent risks associated with mass technogenic and natural explosions. The practical importance of this work is that it has been shown that by means of an ecologically pure vibrational method of atmospheric sounding that it is possible to predict, both theoretically and experimentally, increasing meteo-dependent geoecological risks from external destructive explosions.

3.3.8 Conclusion

A method for studying the processes of interaction of geophysical fields and predicting meteo-dependent geoecological risks for social infrastructure objects and natural environment from powerful destructive explosions has been proposed and implemented. This method is based on the use of seismic vibrators which meet the requirements of geoecological safety and, at the same time, are sources of seismic and acoustic oscillations. Such sources have precision energy and frequency–time characteristics ensuring very good repeatability of the results of investigations.

1. A large series of experiments has been performed with the seismic CV-40 vibrator and test site explosions with seismic stations "Baikal." These experiments were aimed at studying the peculiarities of propagation of acoustic and seismic waves in a wide frequency range and in different azimuthal directions with allowance for the geological and meteorological conditions and the parameters of both sources. In these experiments, the focusing effects of acoustic oscillations in space have been revealed and assessed. Such effects greatly enhance the geoecological impact of mass explosions on the environment determined by the meteorological factors. Specifically, it has been proved that even with a weak wind of 2–4 m/s the ratio between the maximal and minimal acoustic wave levels depending on the azimuthal direction can reach 50. This could be a reason for great ecological hazard from technogenic explosions.

A comparative analysis of seismic and acoustic wave levels allows us to conclude that the major ecologically dangerous effect of ground-based test site explosions is due to acoustic waves whose energy is an order of magnitude greater than that of seismic waves.

Calculated azimuthal dependencies of the focusing effect of acoustic waves in the infralow-frequency range at various wind speeds and "source–receiver" distances have been obtained. A comparison of the calculations and experimental data obtained at the same initial parameters has been made. It was found that meteorological conditions have a greater influence on acoustic wave focusing in experiments than that according to the theoretical results.

In general, the results of this chapter prove that the vibrational method is an efficient instrument for studying the processes of interaction of geophysical fields and predicting meteo-dependent geoecological risks from powerful destructive explosions.

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