Using the capabilities of computer modeling in the software and hardware complex "Safe City"

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Abstract. In this article, the authors consider the possibility of using the Safe City software and hardware complex to ensure human safety and security when living within specific territories. The prospects and results of using ICT and mathematical modeling of processes occurring in a certain territory are substantiated. Attention is drawn to the subsystem "Environmental Safety" of the hardware-software complex "Safe City" and the possibility of its use by law enforcement agencies. The approaches to the assessment and mathematical modeling of geodynamic risks arising in a particular territory are investigated. We studied the negative phenomena affecting a person and recorded by means of the APK "Safe City". The factors contributing to the formation of geodynamic risks in certain territories are analyzed. Forms and methods of using the results of computer modeling of the processes of geodynamic movements in the activities of law enforcement agencies are substantiated. The tasks and functions of law enforcement bodies that are to be aided by mathematical modeling of geodynamic processes in specific territorial systems are highlighted.

1. Introduction

At present, the implementation of human rights is a priority activity of the state and its bodies, however, to date, no state has been able to eradicate violations of the law. Hundreds and thousands of offenses are committed daily, including crimes, the identification of those responsible for which is complicated by a number of circumstances. At the same time, issues related to the dangers of an engineering-technical, socio-economic and medical-biological nature emanating from the geological component of the environment are becoming increasingly relevant and problematic [1]. Effectively ensuring the safety of life of the population is impossible without the introduction of advanced communication systems that can combine the information flows of various security systems, law enforcement agencies, other organizations, with the aim of monitoring and coordinating their activities.

Large-scale informatization of society prioritizes increase in effectiveness of law enforcement agencies, identification of offenses and crimes, as well as recording illegal activities of those responsible with the help of modern technologies and information systems.

The most promising and modern means of ensuring public safety and the rule of law for any state is a combination of technical means and systems located in a certain territory that allow for video surveillance, video recording of current events, as well as to record the parameters of geodynamic
movements and deformations of the upper parts of the earth's crust. In Russia, such an automated
software package is the Safe City system (APK Safe City), which allows not only to process and
transmit video information from street (road) surveillance cameras about offenses and to carry out the
functions of public control of ongoing activities, but also to record emergencies and transmit the
information to the centers of automated data recording [2].

We analyzed the possibilities of using the subsystem "Environmental Security" of the APK "Safe
City" for recording the geodynamic movements and deformations of the upper parts of the earth's
crust, can be used in the following areas of activity: protection of the individual, society and the state
from illegal encroachments; prevention and suppression of crimes and offenses (primarily of a terrorist
nature); detection and disclosure of crimes; prediction of possible geodynamic threats and risks
characteristic of territories of different scales; development of plans for special operations of law
enforcement agencies, based on forecasts obtained by computer modeling, and other areas.

2. Materials and methods

The methodological basis of the study is based on the dialectical method of awareness of the occurring
phenomena, providing a scientific, comprehensive and organizational and functional approach to the
study of geodynamic risks and the practice of fixing and modeling them using information and
telecommunication technologies.

When developing the methodology of mathematical modeling and risk assessment in the
environment of territorial systems, methods of a systematic approach to the study of natural, man-
made and anthropogenic phenomena and processes were applied. In constructing mathematical models
of the geodynamic stability of the territory, methods of continuum mechanics, the theory of
differential equations, and spectral Fourier analysis were used.

Implementation of the constructed models was carried out on the basis of data on environmental
characteristics obtained using engineering-geological, hydrological, hydrogeological, meteorological
research methods, as well as the method of geomorphostructural zoning of the territory.

When developing a mathematical method for optimizing the risk analysis model in specific
territories under the implementation of emergency situations of a geodynamic nature, the methods of
optimal control theory were used. When processing the intermediate and output data, we used the
methods of regression and correlation analysis, as well as the method of spectral-temporal data
analysis. The software for the implementation of the goals and objectives set in the work was
developed in the environment of Borland Pascal and Turbo Basic. Work with databases was carried
out in the environment of MS Excel and MS Access.

Certain aspects of the use of information and telecommunication technologies for assessing and
modeling geodynamic risks were analyzed on the basis of media research, scientific papers and other
literature, including those published in foreign publications.

3. Results of using mathematical modeling to assess geodynamic risks

As you know, the earth’s surface is not stationary, since geodynamic movements and deformation of
the upper parts of the earth’s crust cause changes in soils, load-bearing structures and supports of
buildings, and also lead to the appearance of electromagnetic low-frequency radiation, ionized
particles, gas fluids, and other consequences posing a threat to the safe life of a person [3]. In addition
to natural geodynamic factors, artificially created threats can significantly affect the natural existence
of a person, among which terrorist acts have become widespread. These factors contribute to the
formation of certain stresses in certain areas of the earth's surface or, vice versa, to rarefaction. The
timely receipt of information on the distribution of stress and strain fields is the basis for putting
forward versions of the planning of terrorist acts, and a signal to law enforcement agencies about the
need for operational activities to prevent the alleged negative consequences.

Taking into account gravitational anomalies in a specific area and modeling the processes that take
place, allows you to calculate the possibility of a systemically directed impact and determine the
estimated locations of explosive devices. These circumstances suggest the need for law enforcement
agencies to use the data to organize counteraction to the possible negative consequences of the geodynamic risk manifestations, determining the possibility of their deliberate use during terrorist acts.

Electric, magnetic, light, ionizing, sound and other radiation of various sizes directly affect the health status of the population; however, to date they have not been properly studied.

Using methods of mathematical modeling of the influence of fields of geoelectric nature allows you to expand the application of the agro-industrial complex “Safe City” by obtaining information from the subsystem “Ecological Safety” [4].

In the course of our study, attention was drawn to geoelectric fields and acoustic fields that affect a person and are recorded by means of the APK “Safe City”.

An increase in the geoelectric field during a crisis situation (earthquake, for example) is significant and can reach 200,000 V / m, which is clearly noticeable in areas subject to geodynamic movements and deformations of the upper parts of the earth’s crust [5].

At the same time, studying the platform areas of the earth, it can be argued that the influence of the geoelectric field is insignificant and never perceived in practice, which was justified by the calculations below, based on a relationship that takes into account the charge of electricity that occurs during friction.

$$E(r) = \frac{u\mu qDpS}{4\pi ecr^2},$$  \hspace{1cm} (1)

where $S$ is the area of contacting rubbing surfaces; $p$ is the pressure force between the surfaces of the rubbing bodies; $\mu$ is the coefficient of friction; $r$ is the distance from the surface of the Earth; $D$ is a coefficient depending on the properties of the medium and taking into account the amount of dispersion of the energy of the friction forces; $e$ is the dielectric constant of the medium; $\epsilon$ is the electric constant; $u$ - displacement occurring in the geological environment; $q$ is the value of the elementary charge; $n$ is the number of elementary charges per 1 m$^2$ of the surface.

The results obtained indicate that the magnitude of the geoelectric field generated by micromotors in 1 m$^3$ of the geological environment is not more than 0.002 V / m. The revealed indicator of tension is very low, and is not able to have a negative effect on a person or electrical engineering. Thus, to assess the safety of territories in which a significant part of the population lives, the possibility of a threat to the normal functioning of people increases when approaching epicentral territories, which makes it necessary to take into account the intensity of the geoelectric field [6].

Investigations of the second factor are based on the impact on a person from acoustic fields generated when geodynamic movements occur in a geological environment. Based on the previously used relation, we came to the conclusion that the intensity (strength) of sound is determined by the amount of energy transferred by the wave per unit time through a unit area located perpendicular to the direction of wave propagation:

$$I = \frac{1}{2} pa^2 w^2 v,$$  \hspace{1cm} (2)

where $I$ is the sound intensity; $p$ is the density of the medium; $a$ is the oscillation amplitude; $w$ is the oscillation frequency; $v$ is the speed of propagation of the sound wave.

It is a common knowledge that humans perceive acoustic waves with an intensity of 10-12 to 1 W / m$^2$. Moreover, the Weber-Fechner law states that the volume of sound $L$ is proportional to the logarithm of the ratio of its intensity $I$ to the intensity of the sound wave at the threshold of audibility $I_0$:

$$L = k \log \frac{I}{I_0},$$  \hspace{1cm} (3)

where $k$ is the coefficient of proportionality; $I_0 = 10-12$ W / m$^2$.

The revealed relationships are characteristic precisely of sound vibrations that are audible to humans. At the same time, infrasound is a low-frequency wave process and has great penetrating
power, due to their low absorption (for example, the sounds of volcanic eruptions, atomic explosions can repeatedly go around the globe, seismic waves can cross the entire thickness of the Earth) [7]. Another important feature: infrasound is practically impossible to isolate with any sound-absorbing materials.

We have assessed the infrasound pressure and its level in the city of Orel and its environs in octave bands with geometric mean frequencies of 2, 4, 8 and 16 Hz.

Infrasound pressure was estimated using the following formula:

$$ p = 2\pi vpwu $$

where \( v \) is the frequency of infrasonic vibrations; \( p \) is the density of the geological environment; \( w \) is the propagation velocity of infrasonic vibrations in the geological environment; \( u \) is the amplitude of the displacements in the geological environment. The result of this approach was the calculation of infrasonic pressure, mapping of its equipotential distribution on the territory of Orel and its environs in the marked octave bands with geometric mean frequencies of 2, 4, 8, 16 Hz.

The presented figure reflects the visual correspondence of the calculated equipotential distributions of the levels of infrasonic pressure (for example, the pressure level emanating from 1000 m\(^3\) of the volume of the geological medium with a frequency of infrasonic vibrations of 2 Hz) and the distribution zones of exposure of residents to life-threatening diseases in the city of Orel.

![Figure 1. Equipotential distribution of the level of infrasonic pressure, proceeding from 1000 m\(^3\) of the volume of the geological environment for the territory of the city of Orel (frequency 2 Hz). The most unfavorable sections of the city are highlighted with red lines.](image)

The visual correlation between the levels of infrasound pressure exceeding permissible norms and the territories of the city of Orel with a high incidence in the population is also confirmed by the methodology presented in the work, showing a result of 0.84, which is a significant correlation.

Thus, our results indicate that the geodynamic movements of the earth’s layers generate vibrations in the infrasonic range, which significantly affect the safety of human life in normal conditions.

4. **Directions of use of the Environmental Safety subsystem of the Safe City package**

Mathematical modeling of the processes of geodynamic movements in the geological environment, contributes to the development of sound management decisions aimed at preventing negative phenomena and is an effective tool for quantifying the geodynamic situation of a particular territory.
The most important areas of using the Environmental Safety subsystem of the APK Safe City will be:
- substantiation of scientific approaches in understanding and evaluating the processes of accommodation in certain territories of urban settlements;
- improving the system of information support for the activities of law enforcement agencies on the basis of computer-aided model decision support in various situations for the implementation of their tasks.
- preventive response and development of options for preventive measures in the manifestation of the processes of geodynamic movements in the geological environment [8].

The forms and methods of using the results of computer modeling of the processes of geodynamic movements in the geological environment will be:
- prediction of possible geodynamic threats characteristic of territories of different scales,
- use of forecasts to make strategic, tactical and operational decisions by law enforcement agencies;
- development of plans for special operations of law enforcement agencies, based on forecasts obtained as a result of computer modeling.
- direct computer simulation and study of the processes of geodynamic movements in the geological environment. These models and calculations will result in representation of a number of coefficients, parameters, conditions and factors that have actually manifested themselves in the changing geodynamic environment of a particular region.
- remote use of the capabilities of the APK Safe City via ICT, the result of which will be a mathematical model and recommendations for their use for a specific region [9].

At the same time, in the activities of law enforcement agencies, the study of the directions of mathematical modeling of the processes of geodynamic movements in the geological environment is applicable for the implementation of the following tasks and functions:
- ensuring the geodynamic security of law enforcement agencies, providing timely assistance to their employees;
- assessment of possible risks, the effects of natural factors on the objects and structures owned by law enforcement agencies;
- ensuring the safety of the population and providing them with timely assistance;
- ensuring the security of strategic facilities (nuclear and hydroelectric power plants, facilities of the armed forces, chemical industrial enterprises, etc.) and the values located on them;
- ensuring the proper level of public order;
- ensuring road safety;
- the organization and conduct of anti-terrorism measures, as well as the implementation of other tasks and functions [10].

5. Conclusion
Our proposed approaches to the assessment and mathematical modeling of geodynamic movements in the geological environment allow us to draw the following conclusions.

a) Currently, mathematical modeling of geodynamic movements is not given due attention, despite the fact that the considered manifestations of geological instability can cause catastrophic damage to the population of many vast territories and, therefore, determine the relevance and practical significance of such theoretical and practical studies.

Despite this, theoretical problems and mathematical features of modeling the processes of geodynamic movements in the geological environment are already being applied in the Safe City package, which is of great interest for improving the environmental safety of the population [11].

b) The analysis and reasonable assessment of the influence of geodynamic movements in the geological environment emphasizes their significant differences for the safety and comfort of human habitation on individual territorial entities.
For example, the generation of various electric fields is important for estimation and accounting only in the presence of large seismic events for epicentral regions and territories adjacent to them. Under ordinary conditions, the influence of geoelectric fields is negligible and may be omitted from mathematical modeling of geodynamic movements and safety assessment of individual territories.

A completely different situation is with generation of vibrations in the infrasonic range, which are formed during constant geodynamic movements of the earth’s surface against the background of tectonic processes. The investigated sound vibrations of the infrasonic range can exceed acceptable levels and pose a danger to the normal and safe existence of the population. Thus, a regular relationship has been revealed between the level of generation of fluctuations in the infrasonic range and the state of health of the population living under ordinary conditions in certain territories.

c) It is substantiated that fluctuations of the infrasonic range exceeding the permissible level arise not only in epicentral regions and territories adjacent to them. An assessment of the territory of Oryol, located on the East European platform and attributed to the region with low seismic activity, shows that the influence of fluctuations in the infrasound range is very significant and requires its consideration, which served as the basis for inclusion in the subsystem of the Safe City package.

References
[1] Minaev V A, Topolsky N G, Faddeev A O, Bondar K M and Mokshantsev A V 2017 Geodynamic Risks and Construction Mathematical Models (Moscow: Academy of the State fire service of the Ministry of Emergency Situations of Russia)
[2] Bokova O I, Kanavin S V and Khokhlov N S 2016 Designing terrestrial radio systems for information transmission using specialized software systems Modeling, Optimization, and Information Technologies [in Russian – Modelirovanie, Optimizatsiya i Informatsionnye Tekhnologii] 2(13) Available at: https://moit.vivt.ru/wp-content/uploads/2016/06/BokovaHohlovKanavin_2_16_1.pdf
[3] Dvoryankin S V, Zharkoy R M and Minaev V A 2010 Safe city: intellectual technologies Special equipment and communication 2–3 23–30
[4] Dunin V S 2015 Some aspects of the implementation of the provisions of the concept of the HSC “Safe City” Public safety, law and order in the III millennium: Sat. mat. Int. scientific-practical conf. (Voronezh: Voronezh Institute of the Ministry of Internal Affairs of Russia) 3 19–23
[5] Savich A I, Bronshtein V I and Il’in M M 2000 Geomonitoring in areas of large water-development works with elevated geodynamic risk Hydrotechnical Construction 34 197–203 https://doi.org/10.1007/BF02765769
[6] Todd C S and Engi M 1997 Metamorphic field gradients in the Central Alps J. Metamorph. Geol. 15(4) 513–530
[7] Petrov V A, Leksin A B, Pogorelov V V et al 2017 Geology of Ore Deposits 59 183–208
[8] Alyanskii A L, Bryzgalov V I, Beloborodov V A et al 1998 Experience in designing and operating the electrical engineering part of the Sayano-Shushenskoe hydroelectric station Hydrotechnical Construction 32 498–501
[9] Faddeev A O 2004 Geocological problems of the megalopolis Safety Management [in Russian – Upravlenie Bezopasnostyu] 4 25–27
[10] Menshikov V A, Perminov A N and Urlichich Y M 2012 Technogenic Emergencies: Can They Be Reliably Predicted? In: Global Aerospace Monitoring and Disaster Management (Vienna: Springer) pp 83–125
[11] Bokova O I, Kanavin S V and Khokhlov N S 2017 Training consumers of GLONASS equipment based on a hardware-software simulation complex of navigation monitoring systems for controlling mobile objects Modeling, optimization and information technologies [in Russian – Modelirovanie, Optimizatsiya i Informatsionnye Tekhnologii] 4(19) Available at: https://moit.vivt.ru/wp-content/uploads/2017/10/BokovaSoavtori_4_1_17.pdf