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SCIENTIFIC SOLUTIONS TO PREVENT DUST AND FIRE EMERGENCIES IN OPEN-MINED COAL MINES

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Abstract:
This research focuses on the prevention of landslides, dust, and fire risks in open coal mines, along with associated emergency situations. This research focuses on modern scientific and practical solutions. The primary objective of this study is to ensure process safety, environmental stability, and worker safety. The study utilizes a complex approach based on geotechnical monitoring systems, dust control methods, and fire safety measures, combined with innovative analysis and technology. Open mine stability assessment utilizes modern geodetic methods, satellite monitoring, and digital modeling software. The effectiveness of water spray systems, chemical reagents, and aerodynamic screens was studied. The results clearly demonstrate that sensor systems, which transmit information and early warning mechanisms, can reduce the incidence of such situations by 70-85%. Geotechnical monitoring makes it possible to identify landslide hazards early and prevent them. Dust concentrations can be reduced by 40-60%. The need for innovative technical solutions in Fire Safety, including automated monitoring systems and modern tools, was met. Research and development efforts are essential to improving industry safety standards, developing and increasing production efficiency, and protecting the environment in the process. The proposed solutions enable sustainable development and service delivery.

Keywords: open coal mines, landslide hazard, dust control, fire safety, geotechnical monitoring, emergency situations, innovative technologies, system safety

Introduction

Open-pit coal mines are a modern industry, crucial to maintaining the world's energy resources, yet they are open. Mining activity, with its associated landslides, dust, and fires, poses serious risks to workers' lives, the environment, and the economy, resulting in releases. Over the past ten years, my work in the industry has been plagued by emergency situations. This analysis shows that modern scientific approaches and innovative technologies are required to prevent and manage these risks [1].

Open coal mines landslides. The danger is the geological structure, hydrological conditions, climate change, and my work intensity. The problem of dust and not only workers, possibly, on your health, equipment from work to the exit and environmental pollution, take fire. The danger of coal is spontaneous combustion, a feature, man-made factors, and human factors influence. This is due to three main risks; each closely related to the complex requires a complex approach.

International research shows that 60-70% of mines are open to emergency situations: landslides, 20-25% dust-related events, and 10-15% fires. These indicators confirm the relevance of mine safety in providing new scientific solutions and practical measures [2].

Latest Scopus and Web Data of Science over the years on the bases of indexed scientific in sources open mine safety problems wide In particular, geotechnical monitoring systems , dust control technologies and fire safety a lot to explore take However, this three risk factor combined complex approaches is quite unexplored [3].

Uzbekistan, under these circumstances, is opening coal mines for itself, taking into account typical characteristics (climate, conditions, geological structure, technological processes), local and international experience, harmonized scientific and practical solutions. Our country, my industry, needs international safety standards in accordance with the requirements of adaptation, modern monitoring systems, current growth, and employee qualifications to increase the current of the problems is considered [4].

The main objective of this study is to identify the risks of landslides, dust and fire in coal mines and to prevent the associated emergency situations by taking scientifically based and practical solutions that work with the exit.

The study of the problem consists of the following:

1. Open coal mines landslide risk assessment modern methods of analysis to make and determine their effectiveness;
2. Dust impact reduction innovative technical solutions working Output and in practice application mechanisms justification;
3. Fire safety is a complex system of creation and early warning mechanisms improvement;
4. Emergency management situation digital platform creation and its/its effectiveness assessment.

The study's scientific novelty lies in its discovery of three main risk factors in coal mines (landslides, dust, and fire), including their mutual influence and complex impact analysis. Furthermore, modern sensor technologies, artificial intelligence, intelligent elements, and digital modeling methods were used to prevent emergency situations, leading to a new concept proposal.

The practical importance of the study lies in its effectiveness. The published recommendations and decisions to open coal mines fundamentally improve safety systems, reduce emergency situations, protect workers' lives and health, minimize environmental damage, and increase mine economic efficiency offer the potential.

Explore the results of my industry in enterprises, in particular, open coal mines safety services, designers, research institutes and education in institutions application possible [5].

Literature analysis: Foreign scientists N.A. Strelchuk, M.G. Godzhello, Yu.I. Chigirin, I. Piney, Y. Klinger, G. Fuksch, V. N. Serov, M. Davis, D. Aishton, K. A. Farley, H. Valentin, A. Andrianov, O. M. Todes, M. S. Solovyov, A. N. Kolmogorov, K. Hins, J. S. Townsend, L. Prandtl, E. Taylor, L. S. Klyachko, S. Sachs, A. Einstein, T. Velikanova, A. D. Klimanov, N. Voronin, L. D. Voronina, A. D. Bagrinovsky, S. V. Weiler, P. Rebinder, Y. Borisov, K. Doz, V. Vin, Yu. B. Zeldovich, H. A. Kristoryan, V. V. Stark, Yu. N. Taliev, V. V. Dyakov, S. V. Belov and other researchers made a great contribution to Theory and practice of reducing occupational hazards and preventing fire and explosion hazards at industrial facilities. In our republic, the research of scientists such as O. Yuldashev, A. Kudratov, O. Yuldosheva, T. A. Ganiev, O. K. Abdurakhmanov, Sh. E. Kurbanbaev, O. T. Kasanova, R. R. Nurmamatova, and B. T. Ibragimov has also demonstrated that improving the overall effectiveness of occupational safety systems at industrial facilities is possible. Therefore, a pressing task is to analyze the occupational safety system using the example of the Angren coal mine, identify its shortcomings, and propose advanced approaches, modern technologies, and management mechanisms to address them [6].

Materials and Methods

General Study Design and Objects. This study utilized a mixed-method approach to comprehensively assess landslide, dust, and fire hazards in open-pit coal mines and develop prevention solutions. Large open-pit coal mines (Angren and Shargun) in Uzbekistan and Central Asia were selected as the study objects. Field observations were conducted over a 24-month period. The study process consisted of three phases: field experimental measurements and sampling, laboratory analysis, and mathematical modeling.

Geotechnical monitoring and landslide modeling. Geotechnical monitoring and numerical modeling methods were integrated to study landslide hazard. High-precision GNSS receivers and InSAR satellite interferometry data were used to measure ground displacement in the field. Mechanical characteristics were determined for laboratory testing under three-axis compression (triaxial compression) and direct shear tests. Slope stability analysis was performed using Slide 3 and FLAC 3D software, using the stock balance constraint and limited-element methods.

Dust and dispersion monitoring Analysis of dust dispersion and its/its concentration measurement for modern optical and laser diagnostic methods, current dust particle dispersion composition and concentration in real time measurement for laser diffraction (Malvern Mastersizer) and optical using nephelometric devices (DustTrak DRX). Air samples were used. Conforms to NIOSH 0600 and ISO 7708 standards. The corresponding increase in the number of instruments per quarter calibrated dust aerodynamics propagation prediction was made. AERMOD and CALPUFF dispersion predictions were made for the models used. Meteorological parameters were collected automatically from weather stations through continuous data collection.

Thermal Monitoring and Fire Hazard Analysis. Coal spontaneous combustion risk determination for thermal monitoring, gas analysis, and thermochemical methods were used. At the mine surface, temperature anomalies were determined using infrared (IR) thermal cameras and drone (UAV) aerial photography. Emissions (CO, CO2, CH4) were measured in gas layers using gas chromatography and portable infrared gas analyzers. Thermal decomposition kinetics and activation energy determination were used for thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) methods. Heat and mass exchange processes were analyzed in the COMSOL environment. Multiphysics simulated.

Data reprocessing and verification. All collected data were processed using Python programming language and MATLAB statistics analysis. To prevent complex systems from developing artificial intelligence (AI) and machine learning algorithms, specifically random forest and neural network models, the data was analyzed. The models consist of 10 layers. The cross-validation method (10-fold cross-validation) was used. The results were compared (validated) using international standards (ISO, IEC) and influential scientific sources. The 95% confidence level ($p < 0.05$) and the methodological approach ensured high accuracy and reproducibility.

Results

Geotechnical monitoring and landslide risk assessment. Using artificial results from InSAR satellite interferometry and GNSS reception, manufacturers obtained field information. This analysis showed that the northeast mine on board (annual) shear rate is 45-60 mm. FLAC 3D software was used in supplying the limited elements method (FEM) modeling. The results correspond to this: in the stability zone, the factor of safety (FoS) is 1.25 in dry weather conditions. It rains. During the season (humidity) increases (to account for) to 1.05. This indicator was determined according to international standards (FoS ≥ 1.3). The area has a landslide potential hazard as an existing zone, classifying it as a baseline. Limit balance analysis resulted in my recommendation that the optimal board slope angle is between 38° and 34°. This recommendation was made to reduce the probability of a landslide by 85% [7].

Dust Dispersion and Suppression Technology. The effectiveness of laser diffraction and optical nephelometry measurements using instruments with the same parameters showed that wind speeds exceeding 5 m/s and the movement of the delivery technology during open air movement are sufficient to reduce PM 10 particle concentrations on the surface to 150-180 mg/m^3. An innovative dust suppression system (high-pressure water sprinklers and surface active substances/surfactants added to chemical solutions) was proposed, which then reduced the concentration of dust in the air. In particular, the number of PM 10 particles decreased by 58%, while the concentration of PM 2.5 particles decreased by 64% ($p < 0.01$). The AERMOD dispersion model showed that dust cloud formation with a spreading radius of up to 350 meters was sufficient to predict the need for expanding the sanitary protection zone [8].

Thermal Monitoring and Fire Hazard Analysis Results: Infrared (IR) thermal cameras and unmanned aerial vehicles (UAVs) were used. Aerial photography, as well as observations of 3 miners and 12 heating events, revealed anomalies (hot spots) in the layer. Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) results showed that bituminous coal spontaneously combusted at 65° C. Gas chromatography analysis confirmed that basement airborne carbon dioxide (CO) concentrations exceeding 50 ppm are the most reliable early indicator of fire onset. This is true. "In the COMSOL environment Multiphysics » simulated heat exchange processes showed that coal injection of inert gas (nitrogen) into the layer through combustion temperature for 48 hours indoors at temperatures up to 30° C is possible [9].

Artificial Intelligence-Based Prophecy Model. Accumulated over 24 months, large-scale random forest and neural network algorithms based on big data were used. A digital platform was created using the emergency prophecy model. 10 layers of cross-validation results (10-fold cross-validation) were used. The overall accuracy of the model was 92.4%, with an F -score of 0.89. The model is based on landslide, dust, and fire risks. 48-hour reliability was 88%. The prophecy model was released [10].

Discussion

The obtained results are consistent with those of Zhang et al. and Shi et al. While the study was partially suitable, our proposal is complex and our approach (geotechnical, optical, and thermal monitoring) is more accurate and reliable. In particular, dust suppression. The surface active substance use of the traditional water spray method is 2.5 times more effective than the traditional method, which has been proven to be more effective. The high-precision artificial intelligence model and the mine management system, real-time decision-making, make it possible. This provides results not only for Uzbekistan but also for Central Asia and other open mining regions. It is also practical for the importance of international safety, fully complying with ISO 45001 standards, and approaching suitable standards [11].

Below is my open coal table in accordance with the experimental results taken as quoted:

Table 1. Open coal my main parameters and characteristics

Indicator	Value	Unit of measurement
Mining industry general area	2450	To
Coal to reserve	185	million tons
Annual digging to take size	3.5	million tons/year
My depth (maximum)	285	m
Production release area	840	To
Coal layer thickness	12:45	m
Coating layer thickness	35-120	m
My use deadline	1985 – present	year

Table 2. Results of geotechnical monitoring (landslides) Hazard assessment)

Monitoring zone	Sliding speed (mm/year)	Sustainable Development Index (FoS)	Danger level	Recommendation made board corner
North-east board	45-60	1.05-1.25	High	34°
Southwest board	15-25	1.35-1.48	Short	38°
Eastern board	28-35	1.22-1.30	Middle	36°
Western board	12-18	1.42-1.55	Short	40°
North board	32-42	1.15-1.28	High	35°

Table 3. Dust concentration. Measurement results (PM 10 and PM 2.5)

Measurement point	PM10 (mg/m^3) - Normal	PM10 (mg/m^3) - Innovative	PM2.5 (mg/m^3) - Normal	PM2.5 (mg/m^3) - Innovative	Decrease (%)
Download point	165 ± 12	68 ± 8	95 ± 9	34 ± 5	58.8
Transport route	142 ± 15	62 ± 7	82 ± 8	31 ± 4	56.3
My surface	128 ± 10	55 ± 6	74 ± 7	28 ± 4	57.0
Chopper	178 ± 14	75 ± 9	102 ± 11	38 ± 6	57.9
Average to appreciate	153.25	65.00	88.25	32.75	57.5 ± 1.1

Note: Innovative approach method - high pressure water sprayers + surface active substances (surfactants)

Table 4. Thermal Monitoring and Fire Hazard Indicators

Indicator	Value	Critical boundary	Measurement method
Certain heating anomalies (hot spots)	12 pieces	-	IR thermal camera + UAV
Coal spontaneous combustion start temperature	65°C	-	TGA/DSC
CO concentration (early warning)	50 ppm	100 ppm	Gas chromatography
Critical concentration of CO_2	2500 ppm	5000 ppm	IR gas analyzer
CH4 concentration (explosion risk)	0.8%	5%	Catalytic sensor
Nitrogen from the moment of shipment then temperature decrease (48 hours)	30°C	-	Thermocouples
Fire spread speed (wind) in the absence of)	0.5-1.2 m/h	-	Visual observation

Table 5. Dust suppression technologies comparative efficiency

Technologies	Water consumption (l/m^2)	Dust decrease (%)	Cost (USD/ton)	Application complexity
Traditional water spray	2.5-3.0	35-42	0.15	Short
High pressure water spray (150 bar)	1.2-1.5	48-55	0.22	Middle
Water + surfactant (0.1%)	1.0-1.2	58-65	0.28	Middle
Chemical binder (polymer)	0.8-1.0	68-75	0.45	High
Aerosol system	0.5-0.7	62-70	0.38	High

Technologies	Water consumption (l/m^2)	Dust decrease (%)	Cost (USD/ton)	Application complexity
Complex decision (recommendation) (made)	1.0-1.3	72-78	0.35	Middle

Table 6. Artificial intelligence model prophecy making accuracy

Danger type	Accuracy	Sensitivity	Specificity	F1 measure	Prophecy time
Avalanche	91.2%	88.5%	93.1%	0.87	48-72 hours
Dust explosion	93.8%	91.2%	95.4%	0.92	24-48 hours
Fire	92.1%	89.7%	94.2%	0.90	48 hours
General model	92.4%	89.8%	94.2%	0.89	24-72 hours

Table 7. Emergency situation statistics (24 months observation)

Incident type	Total number	Before taken	Turned to tragedy	Decrease (%)
Small landslide	23	19	4	82.6
Dust concentration increase	156	142	14	91.0
Heat up the anomalies	34	31	3	91.2
Gas separation (critical)	18	17	1	94.4
General	**231**	**209**	**22**	**90.5**

Table 8. Economic efficiency indicators

Indicator	Value	Unit of measurement
The system is currently growing costs	2.8	a million dollars
Annual savings (in emergency situations) will decrease)	1.45	a million dollars a year
Workplace illnesses will decrease	34	%
Production stops to decline	67	%
Return on Arrival (ROI)	1.93	year
Net profit (5 years) within)	4.45	a million dollars

This table open coal in the mine kept complex research transparent digital results display, scientific use in articles (Scopus / Web of Science) for ready considered.

Open coal in the mines gas - dust Wednesday from dangers come outgoing emergency situation situations forecast And prevent take mathematician model working Exit

Following scientific in the article open coal in the mines gas - dust Wednesday from dangers come outgoing emergency situation situations forecast And prevent take mathematician model working go out dedicated. Study basic target my on the surface dust diffusion, gas divorce And fire and explosion processes transparent prophecy executor differential equations system the task is to create. The model takes into account the conservation of mass, momentum, and energy laws based on the Navier-Stokes equations and combustion kinetics. Numerical methods using controlled calculations accurately determine the dynamics of gas-dust mixtures, temperature changes, and explosion waves at high pressures. Production in model mines, ventilation system optimization, dust suppression measures, and emergency planning for preventing situations are important for practical applications. Safety standards should be fundamentally improved, and protection for workers' lives should be made possible. The results obtained confirm the proposed model's high efficiency and practical reliability, providing full confirmation [12].

Also open coal dust dispersion in mines, gas divorce and fire risk modeling for the following equation from the system if used to surface arrival possible was an emergency situation forecast and prevent take events working Exit for the basis will be.

Conservation of mass law (general) mixture)

$$\frac{\partial \rho}{\partial t}+\frac{\partial \rho u}{\partial x}+\frac{\partial \rho v}{\partial y}+\frac{\partial \rho w}{\partial z} \tag{1}$$

Open mines for comment:

- This equation opens my in the field of dust in the air and gas with a mixture of continuous motion describes
- ρ - gas-dust mixture density (kg/m^3)
- y, v, v - wind speed components (m/s)
- This equation describes a dust cloud. My on the surface as a spreading prophecy make for used

2. Dust phase for mass balance

$$\frac{\partial \rho_f}{\partial t}+\frac{\partial \rho_f u}{\partial x}+\frac{\partial \rho_f v}{\partial y}+\frac{\partial \rho_f w}{\partial z}=\gamma_f G_\psi \eta(x_z-x) \tag{2}$$

Practical Application:

- ρ_f - dust concentration (g/m^3)
- γ_f - dust output is a coefficient (mining) related to their work)
- G _ ψ - from the dust source Output intensity
- Safety for significance: this equation using loading, traffic and explosion from work then dust as spread and which in the zone critical to the concentration to reach a certain

3. Coal particle mass balance

$$\frac{\partial \rho_3}{\partial t}+\frac{\partial \rho_3 u}{\partial x}+\frac{\partial \rho_3 v}{\partial y}+\frac{\partial \rho_3 w}{\partial z}=-G_\psi(1-\varsigma_1)\eta(x_z-x) \tag{3}$$

Open mines for comment:

- ρ_3 - solid body coal particles density
- (1 - ς_1) - non-flammable part (gray)
- Fire risk: This equation uses coal particle sinking rate and layer yield to calculate the fire and explosion risk. The thicker the dust layer, the greater the fire and explosion risk.

4. Combustion Process Kinetics

$$\frac{\partial \psi}{\partial t}+u\frac{\partial \psi}{\partial x}+v\frac{\partial \psi}{\partial y}+w\frac{\partial \psi}{\partial z}=\frac{G_\psi}{n\rho_k V_0}\eta(x_z-x) \tag{4}$$

Fire Danger to Importance:

- ψ - combustion level (from 0 to 1)
- n is the number of particles
- ρ_k - coal density
- In practice: this equation of coal spontaneous combustion rate and which at a temperature critical to the situation is sufficient to make a prophecy for used

5-7. Momentum equation (magnitude of motion) conservation)

X -axis according to:

$$\frac{\partial \rho u}{\partial t}+\frac{\partial(\rho u^2+p)}{\partial x}+\frac{\partial \rho uv}{\partial y}+\frac{\partial \rho uw}{\partial z} \tag{5}$$

Y axis according to:

$$\frac{\partial \rho v}{\partial t}+\frac{\partial \rho uv}{\partial x}+\frac{\partial(\rho v^2+p)}{\partial y}+\frac{\partial \rho vw}{\partial z} \tag{6}$$

Z axis according to:

$$\frac{\partial \rho w}{\partial t}+\frac{\partial \rho uw}{\partial x}+\frac{\partial \rho vw}{\partial y}+\frac{\partial(\rho w^2+p)}{\partial z} \tag{7}$$

4.18 - Conservation of energy equation (fire) and explosion kinetics)

$$\frac{\partial \rho E}{\partial t}+\frac{\partial(\rho Eu+pu)}{\partial x}+\frac{\partial(\rho Ev+pv)}{\partial y}+\frac{\partial(\rho Ew+pw)}{\partial z}=QG_\psi\eta(x_z-x) \tag{8}$$

Open mines for comment:

- E - gas-dust mixture total energy (J/kg)
- Q - coal from combustion separated outgoing comparison heating quantity (J/kg)
- G _ ψ - combustion speed (kg/(m^3 s))
- η (x_ z − x) is the combustion zone boundary determinant function
- Practical significance: this equation using my on the surface of the fire, when it begins to heat up the energy as the spread, which in the critical zone reaches the temperature (65° C) and the explosion wave how much? at what distance the propagation will be made [13].

4.19 - Definition of energy and situation equation

$$E = C_v T + \frac{u^2+v^2+w^2}{2}, p * \left(\frac{1}{\rho} - \alpha\right) = RT \qquad (9)$$

Open mines for comment:

- C _ v - gas-dust mixture comparison heating capacity (J /(kg · K))
- T - absolute temperature (K)
- ($u^2 + v^2 + w^2$)/2 - kinetic energy (wind) and broadcast speed (due to)
- p - pressure (Pa)
- ρ - mixture Density (kg/m^3)
- α - particle size limited by the recipient correction coefficient
- P is the gas constant (J (kg K))
- Practical Meaning: When the temperature in a fire zone reaches 500–800 K, the pressure increases sharply, and an explosion wave forms. This equation, using explosion pressure (up to a maximum of 9.3 bar), is possible.

4.20 - Primary school conditions (one-dimensional model)

$$p(x,0) = \begin{cases} P_b, & x \in З\Gamma \\ P_0, & x \notin З\Gamma \end{cases}$$
$$T(x,0) = \begin{cases} T_b, & x \in З\Gamma \\ T_0, & x \notin З\Gamma \end{cases}$$
$$\rho_f(x,0) = \begin{cases} \rho_f, & x \in З\Gamma \\ 0, & x \notin З\Gamma \end{cases}$$
$$u(x,0) = 0; \rho_3(x,0) = 0; \psi(x,0) = 0 \qquad (10)$$

Open mines for comment:

- ZG (Zone) Gassed) – gassed, fire zone
- P _ b , T _ b - fire in the zone of initial pressure and temperature (for example, T _ b = 600 K , P _ b = 1.5 atm)
- P _0, T _0 - mining operations under normal environmental conditions (T _0 = 295 K , P _0 = 101.3 kPa)
- ρ_f - dust concentration in the fire zone (up to 200 g/m^3) critical)
- u (x , 0) = 0 - initial value speed to zero equal (peaceful) situation)
- ψ (x ,0) = 0 - the initial value of the combustion level to zero is equal to
- Practical Meaning: Fire began in terms of the beginning of the development process being modeled.

4.21 - Initial level conditions (3D model)

$$p(x,y,z,0) = \begin{cases} P_b, & З\Gamma\text{"внутри"} \\ P_0, & З\Gamma\text{ "Кроме"} \end{cases}$$
$$T(x,y,z,0) = \begin{cases} T_b, & З\Gamma\text{ "внутри"} \\ T_0, & З\Gamma\text{ "Кроме"} \end{cases}$$
$$\rho_f(x,y,z,0) = \begin{cases} \rho_f, & З\Gamma\text{ "внутри"} \\ 0, & З\Gamma\text{ "Кроме"} \end{cases}$$
$$u(x,y,z,0) = 0; v(x,y,z,0) = 0; w(x,y,z,0) = 0$$
$$\rho_3(x,y,z,0) = 0; \psi(x,y,z,0) = 0; M(x,0) = M_0(x) \qquad (11)$$

Open mines for comment:

- y, v, v - three on the initial speed axis (quiet) (in case = 0)
- ρ_3 - solid body coal remains density (initial = 0)

- ψ - combustion level (initial = 0)
- $M(x,0) = M_0(x)$ - initial value of moisture distribution (coal) in the layer)
- Practical importance: 3D model using my surface every case like fire, dust explosion or gas accumulation cases are fully simulated [14] [15].

Conclusion

Open coal mines should be prepared to address landslide, dust, and fire risks associated with emergency situations, using complex scientific and practical solutions. This work is being conducted. Extensive geotechnical, optical, and thermal monitoring results have shown that these three risk factors cannot be assessed separately, perhaps even individually. The entire system, as well as how to study and manage mine safety, is fundamentally improving. Research using InSAR and GNSS technologies is underway, using mine board stability and estimated board angle optimization, reducing landslide risk by 85 percent. Dust control. Laser diffraction and optical nephelometry based on the work produced a surface-active substance . An innovative spray system was developed. PM 10 and PM 2.5 particle airborne concentrations averaged 60 percent, and discharge potential fire hazards were also monitored. Infrared thermal cameras and gas analysis results, including coal spontaneous combustion temperature and early warning indicators, are also being used . This service has been implemented. Together with this , the gas-dust environment movement and combustion kinetics descriptive special mathematical model (differential) equation system) works out, its using explosion and fire waves propagation dynamics high in accuracy the prophecy was made.
The platform, using artificial intelligence algorithms and digital predictions, collected extensive information to identify emergency situations within 48-72 hours with up to 92.4 percent accuracy. In practice, this complex solution, based on 24-month observation, prevented potential hazards by 90.5 percent, reduced worker illness by 34 percent, and reduced worker release by 67 percent. Economic analysis showed that the system's return deadline was two years shorter than the organization's. In other words, this study examines the results not only in Uzbekistan but throughout the Central Asian region. The study aims to adapt coal mine safety standards to international requirements, protect human life, provide environmental stability, and increase economic efficiency in the industry, focusing on sustainable development and service delivery to meet its goals.

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