University of Miskolc
SPECIFICATIONS OF EARTH SCIENCE

MIKOVINY SÁMUEL
SPECIFICATIONS OF EARTH SCIENCE

Doctoral (PhD) Dissertation Theses

NATURAL AND HUMAN FACTORS AT HAZARDS OF MINING PROCESS AND THEIR CONTROL

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I. Introduction

Mining, as an activity, is as old as mankind. People - not being in possession of the ability of creation – took different objects from their natural environment to serve their needs of convenience, they did this initially for immediate use, later on, and getting onto the path of development they began to form these objects for their own needs.
It may not be considered to be an exaggeration that ancient man is the first miner, who purposefully seeks and obtains a suitable piece of stone from the pile covering the surface with which he could acquire food for living, and prepare leather to be protected against cold.
Without exploration and exploitation of mineral resources, which are basic for human existence; again without production and restoration of industrial environment, which has changed during mining activity, in summary, the mining industry, as purposeful human activity, cannot be imagined technical, or more generally, human civilization. Nowadays it is general to talk about the "crisis" of mining industry here in Europe, especially in Hungary, referring to the declining, more or less ceasing tendency of underground mining both in number and scale of facilities. It is a hasty, unfounded point of view. Mining industry has never been and cannot be in „crisis" as well as it has never been and will not be a „success in industry". Mining is neither successful, nor a failure, it is always adaptive. It is intended to serve and adapt to the needs of the given society, the given era so that it can meet the requirements.

Why is it crucial to prologue this paper on my theses including all my research, analysis, and summary of my findings, as an establishment of my dissertation? Simply because underground mining can hardly be discussed as a working industry in Hungary and it will shortly be true that European underground mining can only be mentioned in past time. Nevertheless, recently gained knowledge about hazardous natural characteristics and human factors during mining process, influences of all those, analysis and evaluation of the proportion of the cases are very important, as they can provide experiences in the field of mining hazards, particularly at the cases of fatal accidents during underground coal mining, within all these more information can be gained about risk factors of mining process, help the operation and again during the start-up activities to reduce risks and improve efficiency of defence against mining hazards.

II. Antecedents and objectives

1. Antecedents

University of Miskolc Faculty of Earth Science
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Individual Doctorate Degree

Field of research:	Geotechnical Systems and Procedures
Thematic group:	Geotechnical Systems,
Subject of research:	Relationship between mining hazards and natural parameters of mineral occurrences, development of the methods of protection against hazards.

2. Plan of Research

The basic objective of the research is to examine the relationship between hazards appearance (basic or natural) during mining activity, their intensity and the natural features of recoverable mineral occurrences; coal, ores, minerals, fluids (oil, natural gas), radioactive material.
As for major natural hazards, water inrush, unexpected gas outbursts, coal and gas (toxic gases, methane, CO_2), coal dust explosion, mine fire (endogenous, exogenous), and rock outbursts risk, and the surface movements and radiating material (gas) were the most significant object of the investigation of mining hazards. Following an analysis of the risk, the target was to develop the methods against mining hazards.

Out of natural conditions, the local (cultivated) depth and thickness of the site, the number of sites, the leaning of the sites, the tectonic characteristics and effects of various mineral characteristics are highly important, their influence has been the subject of research.

A separate chapter analyses the relations between the human factors and the mining hazards, it identifies the cause of the accident, and indicates the official, and safety control functions.

3. Tests used in the methods of collecting material, the structure of the dissertation

The thesis tests analyze and evaluate accidents between 1950 and 1990 for underground coal mining in major (fatal deaths), industrial accidents, major incidents, and then summarize the findings, lessons learned, which no doubt still can be applied to operating systems, these tests can forecast risk assessments and can be applied in the case and circumstances of new facilities.
I studied the records available for inspection, evaluation and documentation of major accidents that were analyzed, the effect of breakdowns - the prevailing geological, mining, theoretical and applied knowledge in scientific, technical, technological, subject to conditionality - the official and non-validated normative professional / service examined the specifications and that these regulations have affected the extent to which 'the accidents and incidents occurring in the number of cases and their severity.
The studies clearly show - what the charts and diagrams also indicate - that the scientific knowledge, technical and technological development of grounding systems, which also suggested some of coercive rules with an effect of a significant reduction of incidents and accidents.

Natural characteristics of Hungarian underground mining are varied. For instance depth of the site shows the variability between 40-800 m, thickness shows the range between 1-16 m, leaning angle is from nearly horizontal to steep (near to 90^o). The geological period of formation of coal plants (the Jurassic Liassic coal of Mecsek, Ajka Cretaceous, Paleocene-Eocene in Central Transdanubia, Nógrád and Borsod-Miocene and early Pliocene of Hungary), the phases of biochemical and geochemical processes of coalification, the petrographic and statigraphic features of the accompanying and covering rocks, fundamentally affecting characteristics of the cultivation are very diverse.

In my essay I tried to find a correlation between changes of the natural characteristics and the effects of these phenomena to the primary risks of mining damages, their occurrence and proportion. Beside natural characteristics, the methods of cultivation and techniques are also very varied, that is why I examined the effects of cultivating methods, the applied techniques on the risks of mining accidents.
My investigations clearly show that the risk of mining activity in the composition of a threat and serious accidents occurred, a significant proportion of incidents – taking into consideration the cultivation system and method, equipment and technology – beside the natural conditions, typically caused by the human factor.

III. Scientific findings and theses

The most significant outcome of thesis is to present the reasons of serious accidents occurred in underground coal mining also showing the extent and proportion of the effects of natural environment and the extent of dominancy of the human factor.

The thesis

1. It can be concluded that there is no direct casual connection between underground coal mining production capacity and its growth, and the number of victims of serious accidents connecting to the hazards of mining activity.

Arguments: According to the study, the theoretical / applied research results, the production technology, technical improvements and a more detailed elaboration of the official rules and more stringent controls of growing production, the number of fatalities has decreased.

The data of production and the figure of lethal accidents at underground mining in the period of 1950 – 1990 are shown in *Table 1,* while the relationship of production and the number of victims are in *Figure 1.*

In the first half of the analyzed period, the volume of production was gradually increased to half (13 Mt to 30 Mt, respectively), and also gradually decreased to the end of the period (30 Mt to 18 Mt). However, the number of fatal accidents, regardless of the production indexes for the whole period shows a tendency of significant decreasing.

Production period	1950-55	1956-60	1961-65	1966-70	1971-75	1976-80	1981-85	1986-90
Production volume (Mt)	112,0	117,8	150,2	138,2	130,7	127,9	125,7	104,9
Lethal accidents (person)	660	418	368	202	153	150	113	64

Table 1 Production data and lethal accidents at underground mining in the period of 1950 – 1990

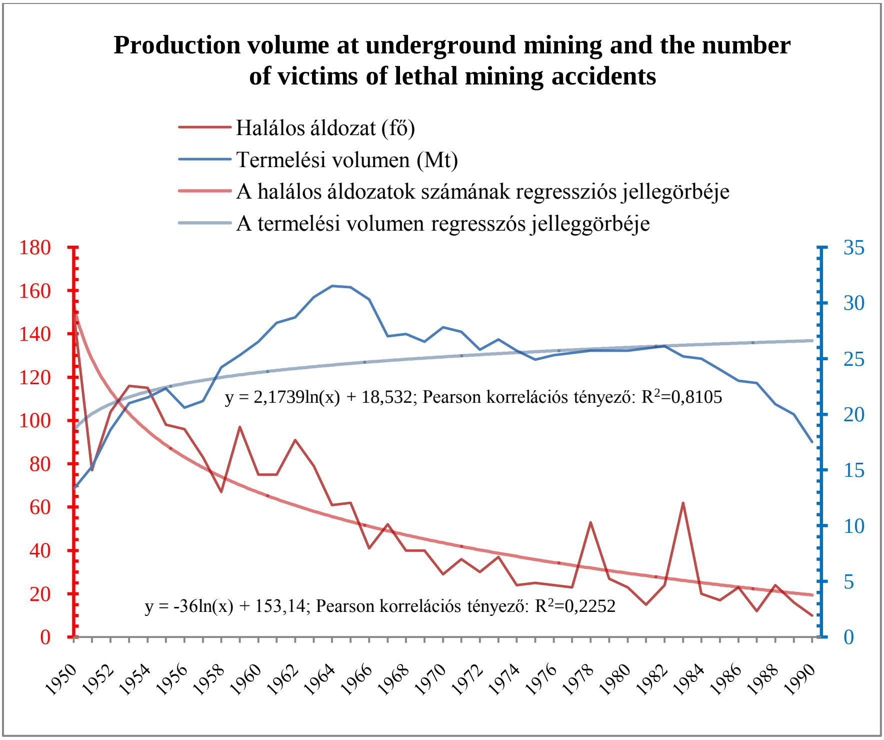

Figure 1 Relationship between production volume and the number of victims during mining activity

The statement of thesis is supported by the correlations of *Table 2* with the feature trend of *Figure 2.*

Research period	1950 -55	1956 -60	1961 -65	1966 -70	1971 -75	1976 -80	1981 -85	1986 -90
Average changes in production volume compared to the period 1950 (%)	144	180	231	212	201	197	194	162
Average changes in the number of victims compared to the period 1950 (%)	73	56	49	27	20	20	15	9

Table 2 Average changes in production volume and the number of victims

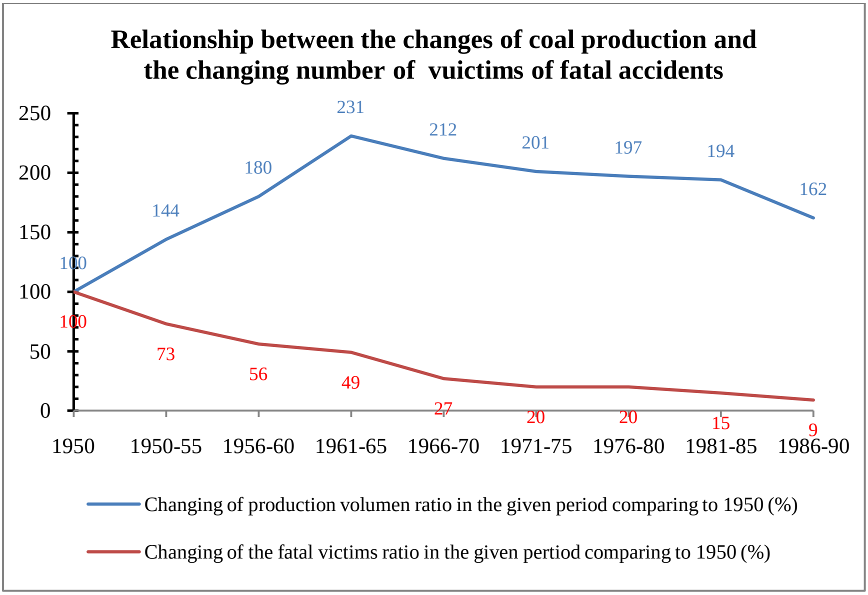

Figure 2 Relationship between the changes in coal production and the changing number of victims of fatal accidents

2. It can be established with the help of examinations of activities carried out in different natural circumstances, which plants with characteristics as steep dips, extremely damp and/or gas or rock outburst-hazardous places are responsible for the 60-70% of lethal accidents in underground mining. As natural characteristics, the most important elements of the hazards in underground mining are the features of mine site that must be emphasized.

Arguments: Correlations of fatal accidents and inclination, carbon composition, coalification, typically CH4 content and degree of tying conditions as natural conditions in the period 1951 – 1990 are shown in *Figure 3* based on data of *Table 3*.
In the examined period, normative safety standards became stricter mainly at the places of steep dips, environments containing more methane, and therefore they were susceptible to fire damp, gas and

rock outburst, and also in the plants, which were more hazardous for water inrush.

Official controls – increased level as well as content – were focused on these plants. In the environment – similarly to non-classified as major mining hazard places - significant safety improvements are made in reliance of production techniques. However, exploration risk factors, as a tendency, are always higher in these natural circumstances than those of in shallower, flat-dipping, not increased (damp, dust, gas danger, etc) activity grade plants.

Natural endowment	1950-1955	1956-1960	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990
Steeply dipping, extremely hazardous to gas/damp and rock outbursts plants	449	257	264	95	91	92	78	43
Flat dipping, non-classified as major hazardous plants	211	161	122	119	61	58	35	21

Table 3 Number of victims of fatal accidents in different natural circumstances

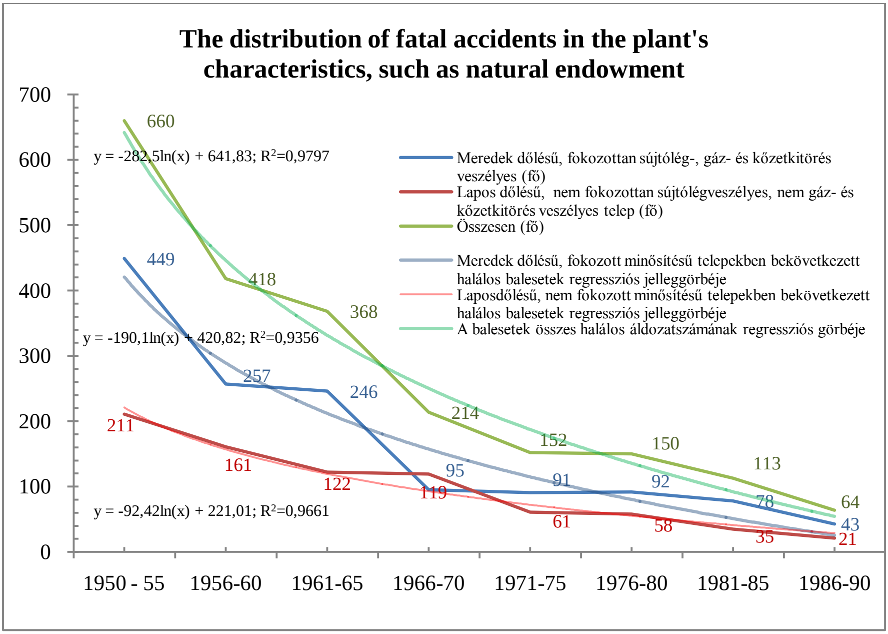

Figure 3 The distribution of fatal accidents in the plant's characteristics, such as natural endowment

3. It can be concluded that out of different natural characteristics risk factors are significantly higher in plants of great depth (typically h> 400 m), so the probability of risks in underground mining activity is significantly higher in places like these than in plants of shallow depth (typically h <400 m), the fatal accident occurred in the share of all fatal accidents prognosis can reach around 60-80% of all fatal disasters.

Arguments: Relationship between fatal accidents during underground mining and depths of the plant as natural characteristics in the period of 1950 – 1990 are shown on *Figure 4-5*, in accordance with *Table* 4.

Natural endowment	1950 - 60		1961 - 70		1971 - 80		1981 - 90	
	case	person	case	person	case	person	case	person
Deep plants	*15*	64	*8*	56	*10*	73	*6*	51
Shallow plants	*7*	51	*2*	11	*1*	3	*1*	6
Total	*22*	*115*	*10*	*67*	*11*	*76*	*7*	*57*

Table 4 Number of cases and victims of fatal accidents in different natural circumstances

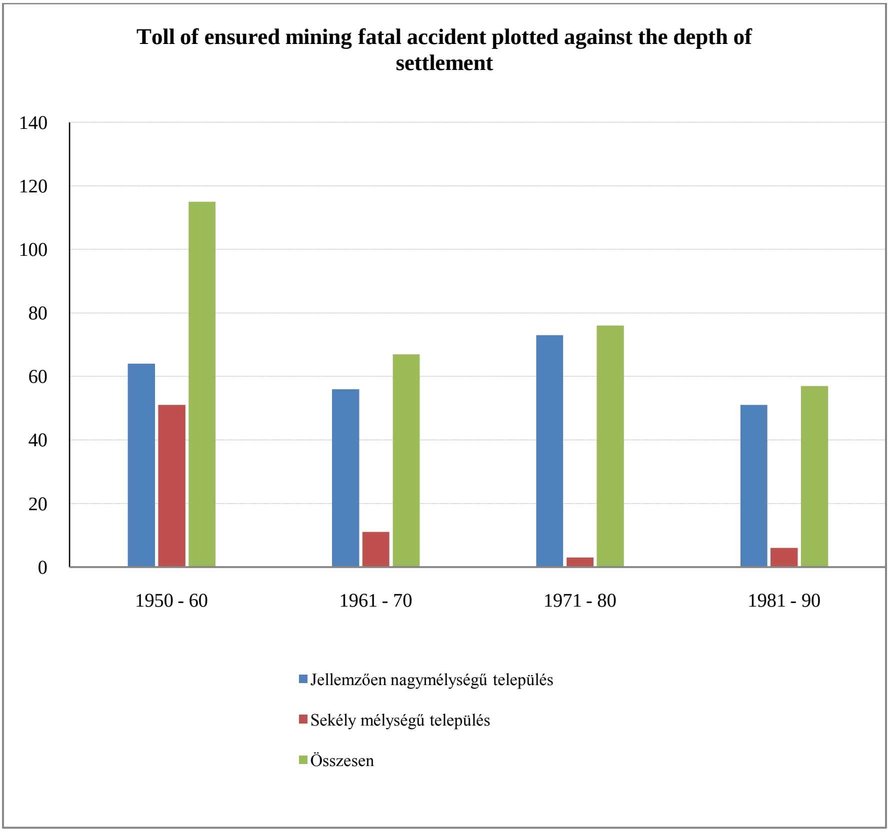

Figure 4 Number of victims in mine accidents in reliance with depth of the plant

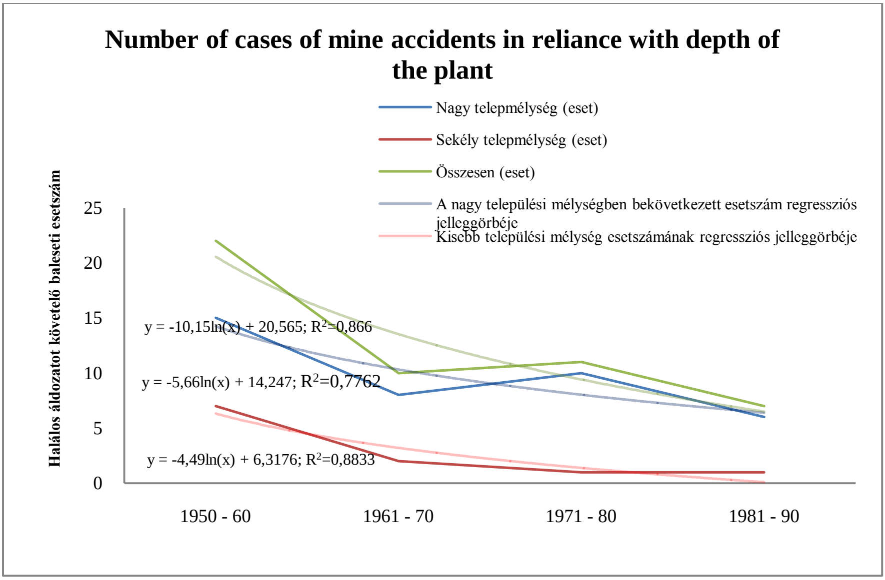

Figure 5 Number of cases of mine accidents in reliance with depth of the plant

4. It can be concluded that proportion of accidents in relation with major risk factors is 3, 3 – 5,2 %, while the share of victims of all fatal accidents is 16 – 29 %.

Arguments: In coalmining the unforeseen non-prognostic main hazards of disasters, like water inrush, damp fire and/or gas or rock outbursts, mine earthquake, mine fire as disasters that come from natural hazards; the numbers and proportions of cases and victims can be seen on *Figure 6* in accordance with data of *Table 5*, while the numbers and proportion of fatal accidents and lethal victims are shown on *Figure 7*.

Elemental hazards	1950 - 60		1961 - 70		1971 - 80		1981 - 90	
	case	person	case	person	case	person	case	person
Water	4	23	-	-	-	-	-	-
Damp and/or coal dust explosion	3	17	6	51	2	29	4	52
Collapse	6	22	2	10	3	15	2	6
Gas outburst	5	16	1	7	4	21	-	-
Mine fire	3	37	2	6	2	21	-	-
Total	21	115	11	74	11	76	7	58
All cases of fatal mining accident occurred and number of victims	524	660	377	462	244	331	135	200
Ratio of the elemental hazards %	4,0 %	17,4 %	3,3 %	16,0 %	4,5 %	23,0 %	5,2 %	29,0 %

Table 5 Number of cases and victims of mining accident occurred in relations with major mine risks

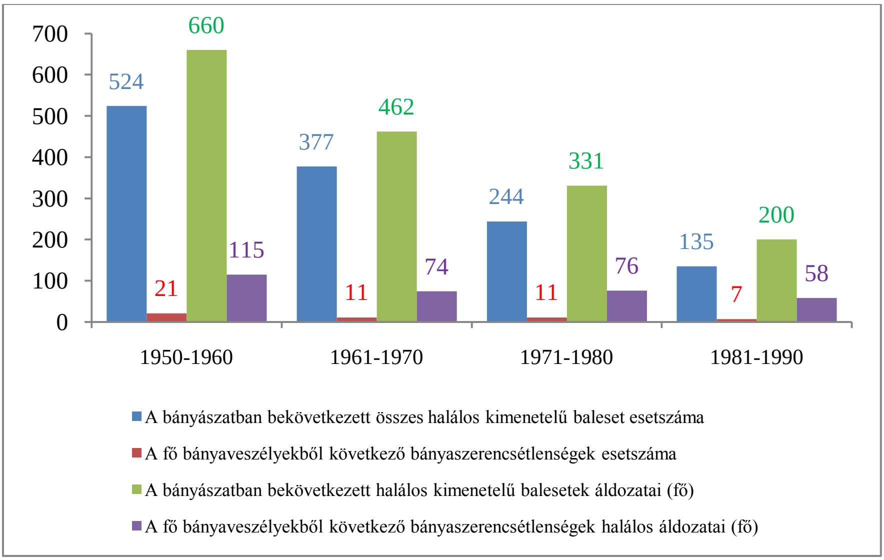

Figure 6 Fatal mining accidents, and those of in relation with major mining risks, number of cases and victims

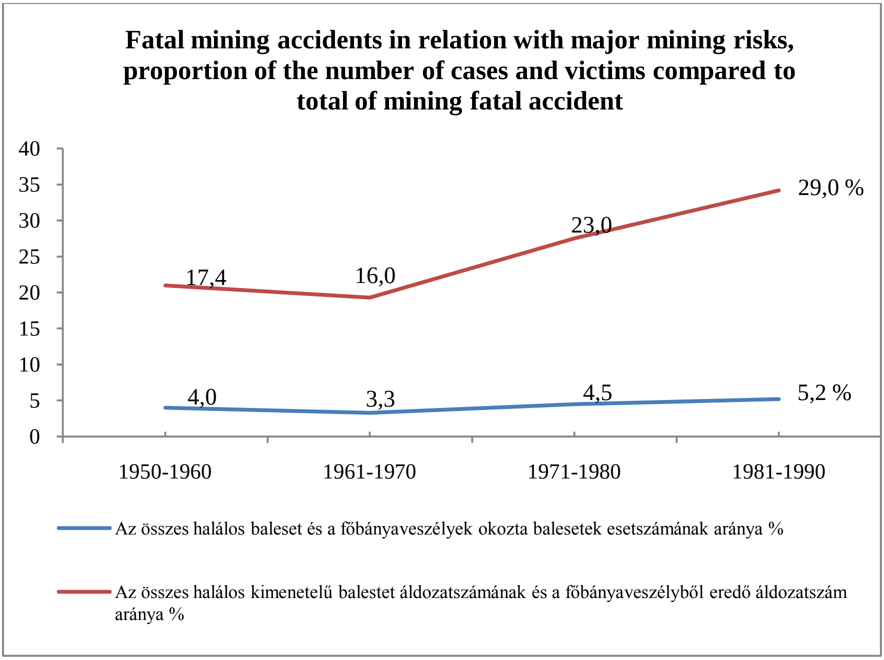

Figure 7 Fatal mining accidents in relation with major mining risks, proportion of the number of cases and victims compared to total of mining fatal accidents

5. The ratio of 95-97%, which did not come from main hazards out of the cases that caused deaths in underground mining, and the total death rate of 63-71 % prove that the primary determinant encountered as the hazards of mine disasters are caused by human factors rather than natural features.

Arguments: I examined the characteristics of accidents occurred, and the roles of human factors in them. *Table 6* includes – as emphasised examples – cases of fatal accidents – but not typical for major hazards – in relation with a certain period. These cases can mainly be led back to human factors; *Table 6* shows these factors, the number of cases and the reasons.

Physical reason of the acccident	***Fatal victims (person) (1971-75)***
Adhesion transport – tram, train	20
Rope transport equipment – brake, ropes, chains, couplings, accessories	4
Continuous conveyor	7
Shaft transport equipment	2
Other transport equipment	2
Cutting and/or loader	4
Electricity	9
Special security equipment (non-debris)	4
Slipping, falling down, bump against sg	8
Explosion (carried in material)	1
Other:	13
Total:	**74**

Table 6 Cases of fatal accidents, not caused by major mining hazards, and their objective reasons

6. It can be concluded that only a part of the fatal mine accidents occur in relation with major hazards of natural conditions as "vis major", most of the cases typically caused by human factors.

Arguments: I examined the conclusion of the tests done in the sample of the period of analyses (1981-85) on reliance to the reasons of fatal cases. *Table 7* includes it.

Main hazard	**Year examined**	**Victims (person)**	**Cause of accident, established by the test**
Rock bursts, rock dropping, from roof, butt end, from side, debris	1981	8	Temporary lack of insurance, lack of knocking irregular caving, the wrong
	1982	7	
	1983	4	
	1984	3	

	1985	5	technology choice
Damp, coal dust explosion, methane flicker	1981	-	**Irregular electrical system or installation, open flames, malfunctioning ventilation, inadequate control, irregular firing**
	1982	1	
	1983	45	
	1984	5	
	1985	4	
Gas and rock outbursts	1981	2	Lack of pilot drilling at front tunnel
	1982	-	
	1983	-	
	1984	-	
	1985	-	
Mine fire	1981	-	
	1982	-	
	1983	-	
	1984	-	
	1985	-	
Water, sludge and sand outburst	1981	-	
	1982	-	
	1983	-	
	1984	-	
	1985	-	
Lack of oxygen, toxic and other gases	1981	1	Unauthorized intrusion, into places that are excluded from the excavation void venting, lack of tests
	1982	-	
	1983	-	
	1984	-	
	1985	1	

Table 7 Reasons of casualties occurred in relation to major mine hazards according to the test (1981-1985)

7. It can be concluded that out of human factors – in accordance with their importance and characteristics in the given period – the most significant reasons of mine accidents are the following:

- the level of theoretical and applied knowledge on geology and mining
- technical and technological level
- level of skill and physical fitness

- management, control level
- subjective factors.

The barrier of awareness of the hazards came from the barrier of recognition of geological, petrophysical, chemical and rock mechanical endowments, or the lack of technical and technological knowledge prevented the possibility to defense against the recognized phenomena.

Arguments: In accordance with the thesis, the presence of human factors, fatal mining accidents occurred – emphasised as typical cases – during the tested period are shown on *Table 8*.

The reasons of mine disasters in the first half of the period (1950 - 1975) – first of all in the cases of disasters at the circumstances of main mining hazards – were the lack of theoretical and applied geological and mining knowledge, beside the listed human factors.

It can be demonstrated that the in the 70s, in the second half of the mentioned period, the rapidly developing theoretical and applied science of awareness, knowledge of the tertiary education of high quality installation, carried out the technical and technological developments that resulted in significant improvements.

The technical scientific level and the technical and technological results support the introduction of a conscious, technically founded normative and legal regulations (new mining legislation and other legal instruments of state control of the by mine authority (for mining safety regulations, controls and increasing the number of professional standards), the mine enterprises special, but mandatory regulations with requiring the operational level of requirements (operational, technical, maintenance, etc).

Mine disaster					
place	***time***	***nature***	***Fatal victims***	***reason***	***Human factor***
Szuhakálló	06.12.1952	Old water inrush	2 (17 people blocked for 6 days)	Lack of pilot drilling	Low-level management, control
Felsőnyárád II. shaft	06.08.0955	Water inrush from outside	7	Floodplain install incline	Low level of geological, mining, theoretical and applied knowledge
Tatabánya Coalmines Company XII/a. shaft	09.03.1972	Mine fire	-	Overheating of electrical cable joints	Low level of technical, technological knowledge, level of skill, physical fitness, level of management, control
Mecsek Coalmines Kossuth mine plant	28.09.1972	Mine fire	7	Rubber drive clutch overheating	technical, technological level, level of management, control, subjective factor.
Tatabánya Coalmines Company	16.02.1976	Damp fire	26 (22 injured)	explosive unintended explosion, collapse	technical, technological level, level of management, level of technical, technological knowledge, level of skill control.
Mecsek Coalmines Zobák Mine Plant	08.08.1981	Gas outburst	2 (35 seriously injured	Provocative explosion	Low level of geological, mining, theoretical and applied knowledge, level of management, control
Oroszlány Coalmines, Márkushegy Mine Plant	22.06.1983	Damp fire	37 (19 seriously injured)	ventilation malfunction, improper blasting activity	level of management, control, subjective factor.

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