Impact of the undergroud coal mining on the environment

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Abstract: *Goal of this paper is to enable the analysis of all the factors affecting environmental quality. Measuring data are systematized by following areas: geographical data, meteorological climate parameters, data about coal bed, characteristics of brown coal "Soko", air from ventilation facilities, and emission of gasses from the boiler house chimney, noise level, soil data and impact of underground mining on land deformation. The analysis of the measurement data allows us to improve control of existing and newly opened coal mines, as well as their ancillary products that act as polluters.*

Key words: *underground coal mine, quantification, land deformation, air pollution, water pollution.*

Introduction

Analysis of impact of the underground coal mining on the environment is a subject of research in many different professions, technical and others, and from different aspects. Underground coal exploitation with its specific technical process that takes place both underground and on the surface, has a multiple influence on the environment of narrower and wider area around the mine. There are numerous papers on environmental influence of coal mine production in many countries: India (Dhar, 2000; Singh, 2005); USA (Ali, 2003; Eggert, 1994; Warhurst, 1999); China (Xiao at el., 2011; Zhao and Gao, 2005) Australia (Eggert, 1994; Frank at el., 2010); Central and Easten European (Filho and Butorina, 2003; Eggert, 1994); Western Balkan (Stuhlberger, 2009); Chile, Peru, Brazil, Bolivia (Warhurst, 1999); United Kindgom (Eggert, 1994); South Africa (Bergstrom at el., 1992). Mineral mining has a negative impact on the environment, as do any use of natural resources. According to environmental theoreticians' exploitation of natural resources leads to faster decline of the environment and this is done mostly from three aspects: depletion of natural resources (Ripley and Redmann, 1990), environmental degradation (Ljubojev et al., 2001; Djordjevic, 2001; Sengupta, 1993; Pataric and Stojanovic, 1989) and pollution of the environmental factors (Stojadinovic, et al., 2013; Singh, 2005; Lilic et al., 1996). Mining activities are intensely treating the environment by all three factors, having in mind the fact that minerals are non-renewable resources (Todorovic and Cvorovic, 1995).

In modern world more than 70 % of material things and objects are consisting of minerals. Here we should add energy, since ¾ are produced by exploitation of minerals (coil, oil, gas, uranium). Beside this, mining as an industrial branch in the production chain, is employing capacities producing for it and capacities depending on the extracted minerals. This is special true for machine building, chemical industry, constructing, power facilities, consumer's goods factories and etc. From these we can conclude that mining was always been a necessity in all the phases of human development (Spitz and Trudinger, 2008).

Most apparent and one of the biggest damages that mining causes is degrading of the environment (Lawrence, 2003; Gupta et al., 2006). Any degrading presents a serious damage to Earth surface and it can be moderated under certain conditions, and not so often returned to a state that is close to its previous look and quality. In exploration of the deposit phase, especially for mining explorations, land is damaged in different intensity, depending on type of exploration. Often in the natural environment we can see the traces of exploratory work (abounded undercuts, trenches, drills, shafts). In general situation exploration works are considered as damages of lesser level, but because of its diversity they cannot be ignored.

Degrading the land by underground exploitation is lesser compared to degrading done by open pit exploitation, but is significant and visible. Here we have slag disposal location and mining site with bunkers and other, open or underground dumping locations. Mining opening (pits, undercuts, inclines) are, also, form of degrading the environment. Especially drastically is the case of damaging the land caused by surface subsidence, when mined area collapses.

Mining exploitation and preparing of the minerals are looking as big water (Bell and Donnelly, 2006) and air pollutants. Very big is the impact of the mining activities on underground and surface waters. Mining objects are intersecting waterways, are changing the micro waterways, regimes of water on area that is exploited are changed. In order to protect the mines from underground and surface waters, waterways are

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diverted and protective objects are building (channels, screens, wells). These activities can sometimes lead to changes in microclimate (Hester and Harison, 1994). There are known cases where building mine water irrigation objects lead to decline in total level of underground waters in the area, which caused a drought in the nearby farming complexes.

Water pollution is a constantly present problem in closer and wider areas around mines. Slag dumps, exposed to atmospheric conditions, by graduate erosion are releasing partials with more or less percent of hazardous matters in the waterway. Cleaning and washing of coil in wet separations without closed system, also presents latent danger for the waterways.

Mining activities are polluting the air, even dough this is type of hazard for the environment is underrated, even by the some experts. Especially important is the emission of dust in the atmosphere in the mine area. Mines have a negative impact on the flora and fauna (Pecharova et al., 2011; Azcue, 1999). Noise, dust, vibrations can lead to withdrawal of some animal species and negative changes in floral world.

Mentioned hazards are only part of manifested and possible negative consequences that mining was on the environment. By defining them it's possible to determine the measures to protecting the environment (Grujic, 1996; Pejcinovic et al., 1994). Total protecting is not possible in most cases, but is necessary to mitigate hazards and get them to an acceptable level.

Methodology

As it sad before, mining as important source of energy was a negative impact on environment processes, which is shown on Figure 1.

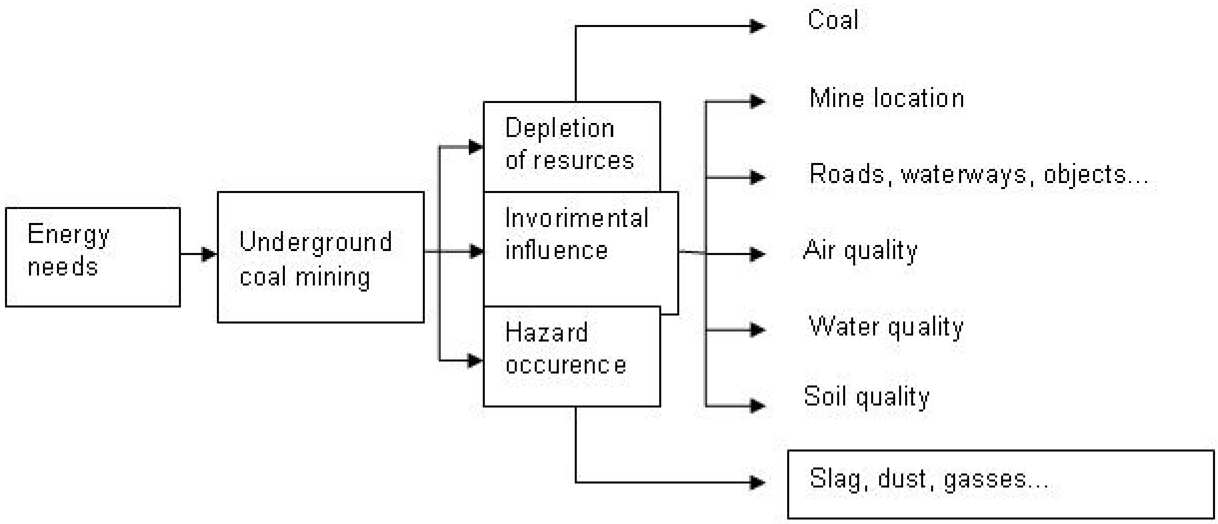

Fig. 1. Global impact of underground coal mining on the environment.

Globally, impact of underground exploitation of coal on the environment can be shown through the impacts that are consequence of human activity (impact on the nature) and influences of polluting (hazardous) matters that are emitted in the waterways, air and land. Impact of individual technological entities is shown on Figure 2.

Overview of the previous and ongoing influence and also assessment of influences is possible only if criteria for over viewing influences, recording the influence parameters, determining the type of parameters, defining the way for measuring or detecting the parameters and way of inputting the parameters into the informatics system and making the criteria for dealing with data for specific parameters.

For recording and analyzing the influences of technological entities shown on Figure 2 methodological approach applied is including a detail analysis of influences of the marked segments of the technological processes on some areas of environment, and then recording the influence parameters of the mining on environmental parameters of mining area. Methodology of recording the parameters is shown in next steps:

a, Coal bed: During this analysis special attention is given to characteristics of coal layer or coal (lignite, hard coal) and all data that is gathered by laboratory analysis and structure of rock bed from which slag is formed during the mining, having in mind that coal and slag brought to the surface are further processed and stowed and by this they are impacting the environment.

b, Climate parameters: Here we need to analyze the data concerning the air temperature, amount of rain, direction and wind speed and then record the normal values for treated climate area.

c, Roads, rivers, land and buildings: Here is analyzed the impact of underground mining on roads, river beds, forests, farms, subsidence and movement of the soil and building located in area of mining.

d, Air pollutants: Underground mining is polluting the air by emitting pollutants from ventilation facility and from water heating systems. Here we considered a boiler house powered by coal.

e, Water pollution: Technology of underground mining can pollute rivers that are flowing on mining areas if waters from separation are released, waters that are pumped out of the pits, water from restaurants, sanitary facilities, workshops and etc.

f, Soil pollution: Underground mining is polluting the surface land by slag that is dumped on the slag pits during mining. For over viewing pollution we need to know the area of the slag pit, amount and content of slag and reaction of slag under the influence of the rain, sun, snow, wind and etc.

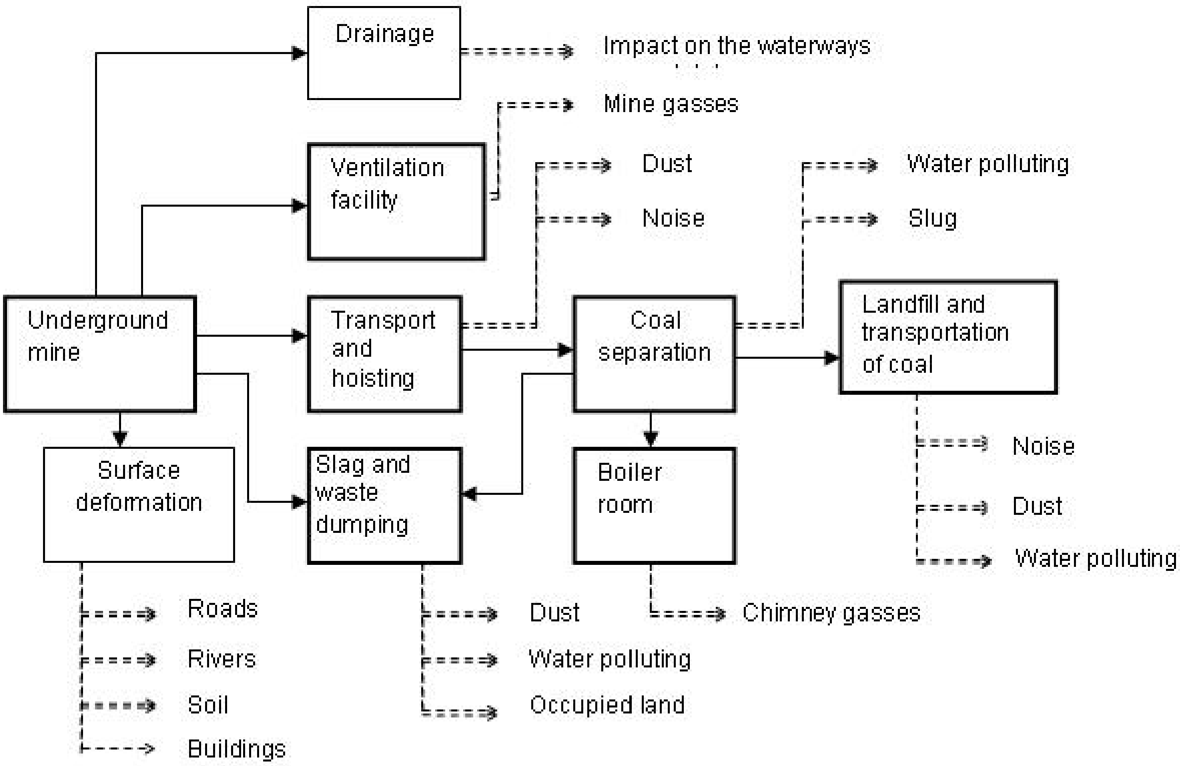

Fig. 2. Influence of technological entities of underground coal mining on the environment.

Results

In methodology section data of potential polluters are systematized. As part of activities on writing this chapter, researches were made on real impact of underground coal mining on the environment of the mine. Data presented are gathered from the mine's monitoring services, rain monitoring and meteorology station, as well from published works, studies, elaborates, and expert analysis done by certified institutes and faculties (Institute 1st May Nis, Mining institute Belgrade, Technical Faculty in Bor, Mining and geology Faculty in Belgrade and etc). Data is systemized by the following areas: geographical (location) parameters; meteorological – climate parameters; data of coal bed; data about coal characteristics; characteristics of air from ventilation facilities and boiler house chimneys; noise levels caused by the machines and facilities; data about soil degradation; data about suspended particles in the mining waste waters; data about mining areas and data about slag pits and landfills.

Data are presented according the mentioned systematization, for "Soko" mine and descriptively, tabular, and graphically.

a, *Geographical data:*

Soko mine is located near the village Citluk, 12 km from Sokobanja. Main road in this area is regional road Knjazevac – Sokobanja – Aleksinac. Sokobanja neogene's basin is surrounded from the east by massive Krstatca and Suplji Kamen, on north by parts of Rtanj, Gole Planine and Slemena, Bukovikom and Raznjem from west side and Ozren and Devica from south, and it covers area of around 220 square kilometers. Near the mine is the spring Moravice and river Izgare with several streams. Altitude of the basin is around

400-700 m. Main road through the exploitation area are road Sokobanja – Knjazevac and local road to Citluk village, mining village Vrelo and spring Moravice. Above the area are groups of individual objects (houses, yards, stables, barns).

b, *Meteorological-climate parameters*:

Air temperature – in table 1 values are shown of average monthly and yearly temperatures (in ºC) and air humidity (in %) for last 25 years.

Tab. 1. Average values of air temperature and humidity .

Mark		Air temperature per month												Average per year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Min.		-4.9	-3.5	1.4	8.2	13.0	15.8	18.1	13.1	11.6	8.5	1.7	-3.7	9.2
Max.		3.1	7.1	8.4	17.6	22.6	23.8	26.7	21.9	18.3	14.8	11.6	5.5	11.7
Average		-1.3	0.6	5.0	10.3	15.4	18.6	20.0	18.9	15.5	10.4	6.2	1.4	10.8
Rel. Humidity	Avr.	84	81	79	72	71	70	65	66	74	81	89	85	76
	Min.	29	26	29	21	22	29	22	19	25	27	43	36	19

Rain amount – in table 2 are shown average monthly and yearly amounts of rain (H in mm/m²) for last 24 years.

Tab. 2. Average values of precipitation.

Mark	Rainfall by month												Average per year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
H aver.	52.2	54.8	55.4	58.9	77.5	76.8	64.6	48.4	46.0	50.8	65.2	64.4	511
H max.	130	108	134	102	162	133	152	164	183	110	114	127	717
H min.	7	12	12	16	14	23	16	6	4	0	22	0	311

Winds – whole area is location dominated by wind from northwest and eastern direction. Winds from north quadrant are showing higher frequency in warmer part of the year (summer). Winds from eastern direction are more frequent in spring and autumn. For Soko mine area there is not a detailed picture of frequency and wind speeds by months (wind rose) but it can be sad that medium speeds for dominant winds are from 2 to 2.5 m/s. In this area maximum expected wind speeds are around 30 m/s. Sokobanjska valley and Soko mine are protected from strong winds from the north by Rtanj Mountain, from east by Krstatca Mountain and Tumba.

c, *Data about coal bed*:

Previous mining – geological systematic researches of Citluk coal bed, three horizons are allocated:

- Padina horizon consisting of sand rock, sandy clay and marl. Thickness of this horizon is up to 100 meters.
- Coal horizon with thickness from 6 to 53 meters consists of one layer of brown coal with complex structure, with under layers of marlstone - of sand clay and white marl. Average thickness of coal layer is 23 meters. Coal layer was angles of 25 to 40 degrees. Slip and overlain of a coal bed consists of coal clay and coal marl.
- Overlain horizon consists of different sediments, where differently colored clays, marls, sand clays and coal clays are dominant, with coal layer of 0.5 to 3 meters in thickness. Thickness of this horizon is around 150 meters.

Data about coal beds are necessary for designing monitoring systems because slag pits are formed from sediments mentioned above.

d, *Characteristics of brown coal "Soko"*

Data of technical analysis of coal sample are shown in table 3. Analysis is done by Mining institute Belgrade.

Tab. 3. Data about coal.

Analysed item		Analysis condition			
		With additional humidity	**With humidity in the tested sample**	**No Humidity**	**No humidity and ashes**
Humidity	[%]	18.70	12.47	-	-
Ash	[%]	12.22	13.16	15.03	-
Shulpure, total	[%]	1.99	2.15	2.46	-
Shulpure in ashes	[%]	0.64	0.69	0.79	-
Shulpure combustible	[%]	1.37	1.47	1.68	1.98
Coke	[%]	46.06	49.59	56.66	48.99
C, fixed	[%]	33.84	36.43	41.63	48.99
Volatile	[%]	35.24	37.94	43.34	51.01
Combustilbe	[%]	69.08	74.37	84.97	100.00
Higher heating value	[KJ/kg]	19.667	21.174	24.191	28.416
Lowee heating value	[KJ/kg]	18.334	19.908	23.073	27.076

e, *Air from ventilation facilities*

Ventilating the Soko mine is done depression, by fan with capacity of 31 m^3/s and depression of 500 Pa. Ventilating facility emits gasses in the air in following concentrations: CH_4 0.2%; CO_2 0.1%; CO 0,001%; NO_x 0,0001%. By using gasses emitted in the air are calculated (m^3/day): CH_4 5.356; CO_2 2.678; CO 26.78; NO_x 0.2678.Ventilating facility is emitting dust in concentrations of 0.2 mg/m^3 of air. Temperature of air exiting form the facility is 20°C, and humidity is 95%.

f. *Emission of gasses form the boiler house chimney*

Warm water for mine needs is produced in the boiler house with two installed coal boilers. Boiler power is 1,1MW, temperature 110°C and pressure 5 bars. Coal used in the boiler house has a thermal value of around 15000 KJ/kg. Daily consumption is around 2 tons. Boiler house gasses are released by concrete chimney with opening of 1x1 m. Height of chimney is 20 m from the ground. Gasses are not treated. From the boiler house chimney emits the following amounts and concentrations of gasses and other pollutants: total amount of smoke gasses 5.400 m^3/h; sulfur dioxide: 4.336 kg/h; 1204 mg/s; 802.6 mg/m^3; carbon monoxide: 0.356 kg/h; 98 mg/s; 65.3 mg/m^3; nitrogen oxide: 0.292 kg/h; 81 mg/s; 54 mg/m^3 and char and ash: 0.207 kg/h; 57 mg/s; 38 mg/m^3. Terrain monitoring has given an estimate of dangerous concentration for the environment, by MDK, on around 185 meters from the chimneys, taking the MDK form SO_2 of 0.15 mg/m^3, and for soot 0.05 mg/m^3.

g, *Noise level*

Significant noise sources are transportation systems on the surface: 100 dB (A), process of dumping-emptying the railcars with coal: 90 dB (A) and ventilation facility: 70 dB (A). Taking into the account that permissible noise level around apartment buildings and public buildings is 30 dB (A) and we can be calculated that not permissible noise level are extends on distance of around 182 m from the noise source of 90 dB (A).

h, *Soil data*

Mining area of 13.8 ha, slag pit 4.2 ha. Soil damaged by soil subsidence above the Stara jama: Forests 8.76 hectares; Areas for foresting 3.9 hectares; Meadows 6.84 hectares; Grassland 10.8 hectares; Grains 4.1 hectares; Orchard 3.21 hectares and Fodder 5.59 hectares. Area that is exposed to the influence of the coal mining in the west wing is 60 ha.

i, *Impact of underground mining on land deformation*

Surface is exposed to deformations caused by coal mining in B6 field; there are significant natural and infrastructural objects, as: regional road Soko Banja – Knjazevac; river Izgare; individual households; mine shaft for hoisting and mine building.

Diagram on figures 3 and 4 are showing prediction for horizontal and vertical shifts of Soko Banja Knjazevac road and riverbed of Izgara river and soil on which individual objects are building depending on predicted rate of underground exploitation a shows on figures 5 and 6.

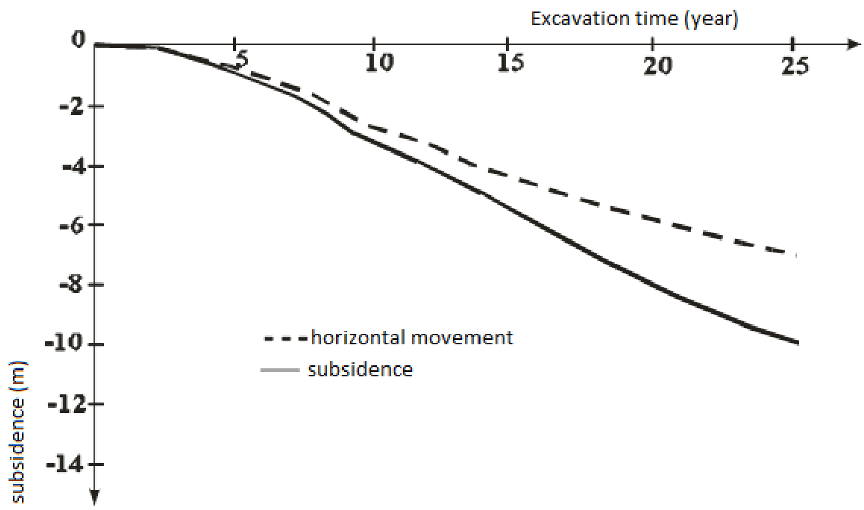

Fig. 3. Subsidence and horizontal movement of roads.

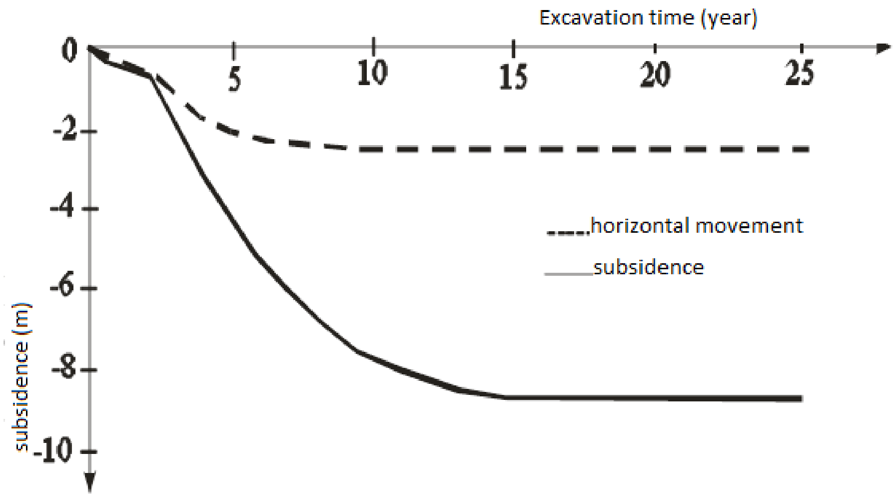

Fig. 4. Deformation of river bad.

For marking the direction of horizontal movements it is adopted that positive is marking the south-north direction, or left-right shore or Izgare River and left-right for Soko Banja – Knjazevac road. Predicted rate of exploitation is 200000 tons per year.

Based on the geometrical shape and dimensions of the future undercut massive, by using calculations and previous geodetic measures, is calculated that there will be a significant land deformation above the mining field.

Deformation of Soko Banja – Knjazevac road: part of the road that is threatened is around 1050 meters (from stationary point 0+450 to stationary point 1+500). Part of the road 400 in length is seriously threatened (between 0+850 and 1+250), where is expected to subsidence for 12 m and horizontal movement of the land, by 7 meters in southern direction. Figure 3 shows a diagram of land moving development in dependence to time of exploitation.

Deformations of Izgara riverbed: influence of underground exploitation is showing its influence on the riverbed on 900 meters section (between stationary point 0+800 and 1+700). Section from stationary point 1+100 to 1+400, long around 300 meters, is significantly threatened. Maximal subsidence is around 8.5 meters, and horizontal movement around ±2.5 meters. Figure 4 shows the diagram of horizontal and vertical deformations of Izgara's riverbed in dependence to time of coal exploitation.

Deformations of land with individual and mining objects: individual object in the mine area are build on location marked with A, B, C and D on land threatened by horizontal and vertical deformations: location on the left side of the river, Krecnjacka valley, mark A; location on the left side of the river, downstream from the previous location, mark B; location on the left side of the river, and in wider river valley, mark C and locations on the right side of the river, mark D.

On figure 5 and 6 following are shown diagram of land deformation with individual objects and damages to the object caused by horizontal movement of the land.

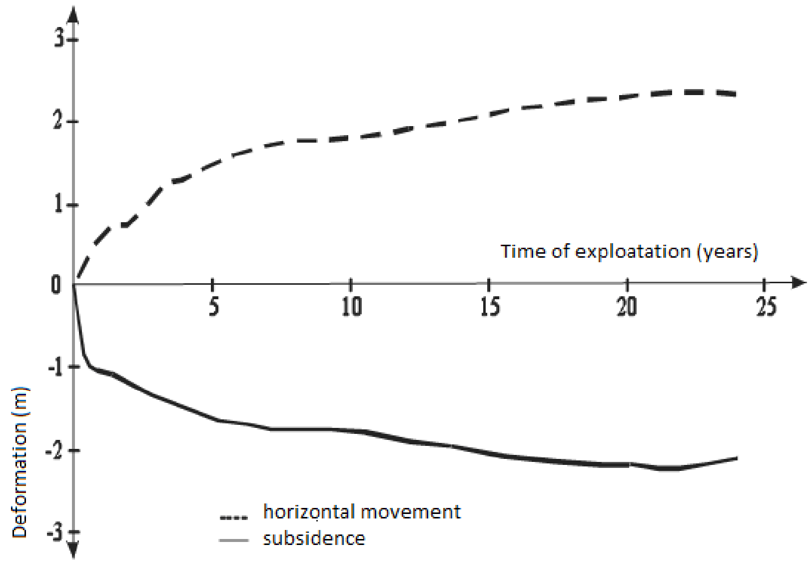

Fig. 5. Deformation of soil with individual objects.

Fig. 6. Examples of damages to a private building caused by a terrain deformation.

Maximal subsidence of the land is around 1.9 meters, and horizontal movement of the land toward north is approximately 2.4 meters.

By same methodology deformations are considered and for other location of individual object, and data for maximal deformations of the land are shown in table 4.

Tab. 4. Maximal deformation of soil on locations with individual objects.

Object location	**Max. of subsidence** [m]	**Max. movement** [m]	**Direction of movement**
A	0	0.1	South
B	1.3	0.8	North
C	5	0	-
D	3	0.5	North

From soil deformation on mining object location, objects are divided in following groups: export shaft, labeled IO; administrative building, toilets, restaurant, labeled UZ; halls, warehouses, workshops, labeled HMR and mining entrance, labeled UR.

By this applied methodology, values and diagrams of soil deformation for these object groups are calculated. Values of maximal deformations are shown in table 5.

Tab. 5. Maximal soil deformations on mining objects locations.

Groups of objects	Max. subsidence [m]	Max. Movement [m]	Direction on movements
IO	0.05	0.03	South
UZ	0.5	0.75	North
HMR	-	-	-
UR	0.5	0.5	North

From this analysis of underground coil exploitation impact on the environment, it can be concluded that this type of mining mostly effects the occupation and change of purpose of the soil and on formation of deformation of soil, roads, rivers, settlement and other objects.

Conclusion

Information that can be gathered from environmental information system can be employed for different purposes by different users. Information about soil deformation, while coil exploitation is still active, can be used preventively for timely implementation of necessary actions, since level of deformation and time period of this deformation can be predicted. Information of final soil deformation after is finished with underground exploitation, making it possible for environmental planers to undertaken final actions for deformations recovery, reclamation of remedied soil and planning of building new object on soil that will not be subjected to deformations.

One of the questions of relations between mining and environmental protection is a problem of quantification of the impact of mining exploitation on the environment. As with technical sciences, parameters in mining are presented with its numerical values. For some solution in mining to be valued from environmental aspect it needs to do an evaluation of this relation. For that one of the priorities for the experts dealing with these issues is to make norms and numerical indicator of harmfulness to the environment. Beside this, environmental protection in mining must have its economical valorization; or– cost-benefit ratio must be set, while calculating the wider social aspects (Grujic, 1996).

Environmental protection in mining should be conducted by four basic directions: searching for adequate environmental protection for existing technologies of exploitation and raw material preparation; researching and applying new technologies in all areas of mining that will posse minimal threat to the environment; mitigating and recovering the negative consequences of mineral exploitation and permanent education of mining staff on all levels, for environmental protection.

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