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A PRELIMINARY ASSESSMENT OF CLIMATE CHANGE IMPACTS – IMPLICATIONS FOR MINING ACTIVITY IN POLISH COAL REGIONS

It is widely known and accepted that the global climate is changing with unprecedented speed. Climate models project increasing temperatures and changes in precipitation regimes which will alter the frequency, magnitude, and geographic distribution of climate-related hazards including flood, drought and heat waves. In the mining industry, climate change impacts are an area of research around the world, mostly in relation to the mining industry in Australia and Canada, where mining policies and mitigation actions based on the results of this research were adopted and applied. In Poland, there is still a lack of research on how climate change, and especially extreme weather events, impacts mining activity. This impact may be of particular importance in Poland, where the mining industry is in the process of intensive transition. The paper presents an overview of hazardous events in mining in Poland that were related to extreme weather phenomena. The needs and recommended actions in the scope of mitigating the impact of future climate change on mining in all stages of its functioning were also indicated. The presented analyses and conclusions are the results of the first activities in the TEXMIN project: *The impact of extreme weather events on mining activities*, identifying the most important factors resulting from climate change impact on mining.

Keywords: climate change, mining activity, extreme weather events, climate change impacts on coal mining, transition of coal regions

1. Introduction

Research into climate change and its consequences is recognized as highly important in European Union countries and around the world. Awareness of climate change exists in Poland, but this issue is not widely recognized as a priority and therefore there is a relative lack of public

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discourse, focused interdisciplinary research or action from policy makers. The observed effects of climate change in the country are not dramatic and their interpretation is complex, as there are many factors to consider. The combination of the high natural variability of hydro-meteorological phenomena and high levels of uncertainty in future projections makes public discussion difficult (Kundzewicz et al., 2017). At the same time, there is an increasing level of knowledge about extreme meteorological phenomena, the mechanisms of their formation and their consequences (Beniston & Stephenson, 2004). The term "weather" is used to describe what we experience on a short-term basis (e.g. daily, weekly or monthly) in terms of variables such as temperature, precipitation, humidity, wind and atmospheric pressure. The term "climate" corresponds to the weather conditions that prevail in a particular region throughout a particular period of time, typically 20-30 years. There is now an overwhelming amount of scientific evidence, which is based on a wide range of indicators, that suggests that climate change is occurring and in particular the global climate system is warming up (IPCC, 1995; Oreskes, 2004; IPCC, 2007; Ackerman & Staunton, 2008; Lemmen, 2008; Giorgi & Lionello, 2008; Doran & Zimmerman, 2009; Global Climate change..., 2009; Anderegg et al., 2010; Cook et al., 2013; EC, 2013; SPA, 2013; IPCC, 2014; Kundzewicz et al., 2017; Pecl et al., 2017; USGCRP, 2018; Climate Change..., 2019; IPCC, 2019a). It is worth to mention here that the number of papers rejecting AGW (Anthropogenic, or human-caused, Global Warming) is a miniscule proportion of the published research, with the percentage slightly decreasing over time. Among papers expressing a position on AGW, an overwhelming percentage (97.2% based on self-ratings, 97.1% based on abstract ratings) endorses the scientific consensus on AGW (Cook *et.al.,* 2016). The evidence for global warming includes observed increases in average atmospheric and oceanic temperatures, widespread melting of snow and ice, and rising sea levels (Global Climate change..., 2009; Collins et al., 2013; USGCRP, 2017; IPCC, 2019b). If the global climate system continues to change, as it is predicted, there will be greater variability in temperature and precipitation (Schellnhuber, 2008).

Climate change has been the subject of global research for many years, and the phenomena resulting from these changes are a problem on an international scale. The significance of this problem is illustrated by the establishment of the Intergovernmental Panel on Climate Change (IPCC) as early as the 1980s, with its main aim to "provide scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation." (IPCC, 1998). The IPCC's regular assessment reports and special reports focused on specific climate change related issues not only organize the state of knowledge but also stimulate further research (IPCC 1995; IPCC, 2007; IPCC, 2014; IPCC, 2018; IPCC, 2019a, IPCC, 2019b).

The aspects of extreme weather events affecting the functioning of society and the economy are recognized mostly in terms of the results of catastrophic impacts, i.e. floods, storms or drought affecting particular areas. In the case of the mining industry in Europe the potential impacts of climate change were not an area of particular interest. The scope of the research conducted has changed in recent years, the relationship between climate change and mining has so far only been considered in terms of the impact of mining activities on all elements of the environment, including the climate, even though climate change and its consequences can significantly affect the operations of the mining industry.

So far similar research was carried out mostly in Canada and Australia, due to the specifics of the geographical location and mining activities in these areas (Pearce et al., 2009; Pearce et al., 2011; Hodgkinson, 2010; Mason et al., 2013; Mason, Giurco, 2013; OCCIAR, 2017). There is an increasing need to carry out this research in Europe, where climate change, especially extreme weather phenomena, can have complex impacts on the mining sector. Assessing and responding to the risks deriving from climate change on the operations of the mining industry is very important for all 42 regions across 12 EU countries (Bódis et al., 2019), where coal is still mined, including these mining regions (defined at a territorial classification of NUTS-2 level), tackling currently the challenges related to the transition to a low carbon economy, named in late 2017 as Coal Regions in Transition (CRiT) according to the relevant terms of reference (EC Coal Regions in Transition Platform, 2017). The transformation of coal regions is expected to achieve the objectives of European Green Deal. The decline of coal-based energy production is an ongoing reality in Europe. Since 2012, total coal power generation has dropped by almost a third in the EU. The declining use of coal has led to mines closing down in a number of regions across Europe. The Across EU countries transition to cleaner forms of energy and innovative technologies, such as carbon capture and storage, is imperative to meet the EU's commitment to reduce CO_2 emissions by at least 40% by 2030 and to become the world's first climate-neutral bloc by 2050.

Although the shift to a low-carbon economy presents many opportunities, economic and social impacts in many coal regions should not be ignored. Moreover, in reality of climate change, transformation of mining from active to closing down, should be properly addressed concerning hazards derived from extreme weather events and climate change factors (Alves Dias et al., 2018). Changing climatic conditions may have both direct (operational and performance-based) and indirect (ensuring security of supplies and rising energy costs) impacts on the mining sector (Sharma et al., 2013; Rüttinger & Sharma, 2016). These include, among others: water-related impacts (droughts, floods, extreme rainfall events), heat and temperature change impacts (heat strokes) and changes in atmospheric pressure. Climate change affects the entire value chain in the mining industry, from exploration, extraction, transport to closure (Pearce et al., 2011).

Additionally, an increase in climate-related hazards, as mentioned above, will affect the viability of mining operations and may potentially increase operating, transportation, and decommissioning costs (Odell et al., 2018). The impact on the mining industry can be analysed from two standpoints (Yupari, 2010), i.e. policy/regulatory effects and potential physical impacts. There are many studies related to climate policy issues which include the management of emissions. According to a study performed by Ford et al. (2010), mining companies are, generally, more focused on policy and mitigation initiatives, in order to reduce carbon emissions.

In recent years, there has been a slow increase in the number of literature concerning the potential consequences and physical impacts of climate change on mining. However, it is still small compared to the number of papers on the processes and modelling of climate change on varying scales. Lemmen et al. (2008) reports that our understanding of the implications of climate change for major industrial activities remains limited, with climate change research and action typically focusing on mitigation.

Referring to Pearce et al. (2011) and Damigos (2012), respectively, it should be noted that Canadian and Greek mining companies have been reluctant to spend money on adaptation measures, due to the lack of research on how climate change will affect mining operations. This leads to the assumption that it is easier to react to a situation that has already occurred and simply accept that extreme weather events contribute to the emergence of additional cost. Damigos (2012) estimates that the costs of climate change to the Greek mining sector could be total US$ 800 million by 2050, owing to factors, such as decreased water supply, destruction of equipment in extreme weather events, and loss of productive labour hours due to an increase in high-heat days. Necessary adaptation measures, however, would cost only US$ 312 million, indicating a financial incentive to invest in adaptation measures rather than only minimising the damage (Odell et al., 2018).

There is a lack of investigations concerning the impact of climate change on the Polish mining industry, which is now in the transition process. From 65 previously active coal mines in Upper Silesian Coal Basin (GZW) only 21 continue coal exploitation, while rest of mines is closed down with active dewatering of interconnected excavations. In Lower Silesian Coal Basin (DZW) since 1990s coal mining has been abandoned, while environmental threats still occur. In Lubelskie Coal Basin (LZW) the possibilities of further development of exploitation are prospective, as only about 0,9% of prospective area for coal deposits is currently exploited (Malon & Tymiński, 2018).

Research on mining activity and climate change impacts was carried out by Łączny et al. (2011), whose survey on the main climate impacts were conducted with the participation of the mining sector. Mine closure, mine rehabilitation sites and the necessity of mine dewatering are activities which are also vulnerable to climate change impacts. Resources Canada (2007) recognizes that there is little scientific literature which evaluates the role and impact of climate change on mine rehabilitation projects, despite the vast number of closed and abandoned mines. Nelson & Schuchard (2010) indicate that natural disasters and changes to precipitation patterns may damage mining infrastructure, requiring additional measures to ensure its stability. Existing assets may no longer be able to meet original design parameters. Changing temperatures and rainfall patterns will influence closure design, and may increase financial liability and monitoring requirements. Pearce et al. (2009) identified the possibility that climate change could present a potentially serious risk for closed or operating mines, where planning was based on current and past climate trends, and that abandoned mines sites had not yet been assessed for vulnerability to this issue. In their follow up work, Pearce et al. 2011 identify a number of instances where abandoned mines have already been affected by changing climatic conditions.

Europe has a great deal of abandoned mines, and areas with old shallow mine openings also have high risk potential due to climate change. There has, been some relevant local studies in this area. Gombert & Charmoille (2010) investigated the impact of climate change on the stability of underground voids. The impact of higher precipitation provokes a higher rate of disintegration of rock. This process directly affects the surface and the safety of the population. Klinger et al. (2012) have looked at the formation of secondary water in old and inaccessible shallow mining openings, where there is a higher risk of pollution of water bodies, due to the flushing of oxidation products. Wrona et al. (2016) have studied gas emissions from old mine shafts in relation to barometric pressures drops (which would increase in frequency and level during severe weather events).

2. Assessment of climate impacts on the coal mining industry in Poland

Regarding the direct effects of climate change on the mining industry, a recent study by the International Council for Mines and Metals (ICMM, 2019) states that extreme weather events and longer term shifts in climate patterns have the potential to:

- damage fixed assets and mining equipment;

- affect the ongoing performance of facilities that have long life spans, such as tailing dams, water and water rock storage facilities (stability of the slopes of waste heaps);
- lead to changes in output;
- disrupt supply chains;
- cause shifting patterns in demand for products.

It can as well disrupt energy supply form mining activities (black outs, power cuts and restrictions in fuel and energy supply).

Additionally, it's highlighted that if left unmanaged, climate change can weaken a company's balance sheets through:

- loss of revenue as productivity declines;
- impacts on asset values and the cost of insurance;
- increased costs as raw materials become scarce (e.g. water) or operations need to make unplanned investments to adapt (ICMM, 2019).

The basic production stages of the mining sector are mining and processing, as well as transport and storage. Mining plants are always accompanied by waste generation. Environmental components, including climatic phenomena, are also subject to the components of individual stages and related infrastructure. In the mining sector, therefore, one can distinguish groups of elements of the impact of climatic factors associated with individual stages of operation:

- mining – impact on: selected and backfilled rock mass, shaft towers, subsidence basins, mining damage, machinery parks, large-scale excavations and opencasts,
- processing – impact on: cubature (construction) facilities, and ponds (constructed as concrete reservoirs or settling water ponds),
- transport and storage – impact on: internal (operational) transport, water transport, pipelines, conveyors, railway tracks and sidings, internal and access roads, material and product warehouses,
- waste – impact on: sub-surface and above-surface waste heaps, tailings.

In order to determine the threat to the sector and its elements, as well as to assess its sensitivity to climatic factors, Łączny et al. (2011), conducted a survey in which representatives of 29 hard coal mines and 4 lignite mines participated. Studies have shown that generally the following factors: floods, torrential rain, downpours, hurricanes, freezing rain, long-lasting ice cover and gusty winds have a negative impact on all elements of the sector, i.e. mining, processing, transport and storage, waste, regardless of the division into hard coal and lignite. High sunlight and low water level have positive impacts. The most endangered elements of the sector, without differentiation between hard coal and lignite, are transport and storage of products and waste. This is probably related to climate-sensitive surface infrastructure and building constructions, and the way the waste is stored in the form of landfills. Climatic factors that have the greatest negative impact on hard coal mining are torrential rain, downpours and hurricanes on transport and storage, floods and freezing rain on all elements of the sector. There is a visible relationship between the negative impact of gusty winds and long hot periods on all elements of the hard coal mining industry. Factors with a currently recognized marginal impact on the sector's elements are soil moisture and high humidity, although future research may prove their bigger significance. The surveys revealed the significant impact of climatic factors on the main processes in mining sector such as exploration, extraction and transport, which should lead to the intensification of further research, especially in the scope of preventing their negative impact and in the aspect of risk management (Łączny et al., 2011). A research survey carried out 10 years ago did not take into account coal industry transition and did not recognize the trends of climatic parameters, such as temperature, precipitation or atmospheric pressure.

The assessment and minimisation of the impact of extreme weather conditions on mining operations in Poland should also consider the ongoing mining sector transition process. Climate change projections should be taken into account when restructuring and during the design of mine closure actions.

Due to the fact that the current situation in Polish mining regions is diverse in terms of mining status, as already mentioned in earlier part of this paper, it is important for the complex study on the climate change impact on mining in Poland to take into account: climate change impacts and risks for the area where mine closures and flooding of excavations have been completed (Lower Silesian Coal Basin – DZW), for the area in the transition process of coal mining where active and abandoned mines are interconnected (Upper Silesian Coal Basin – GZW) and for the area where active exploitation is currently carried out and still planned for future (Lublin Coal Basin – LZW).

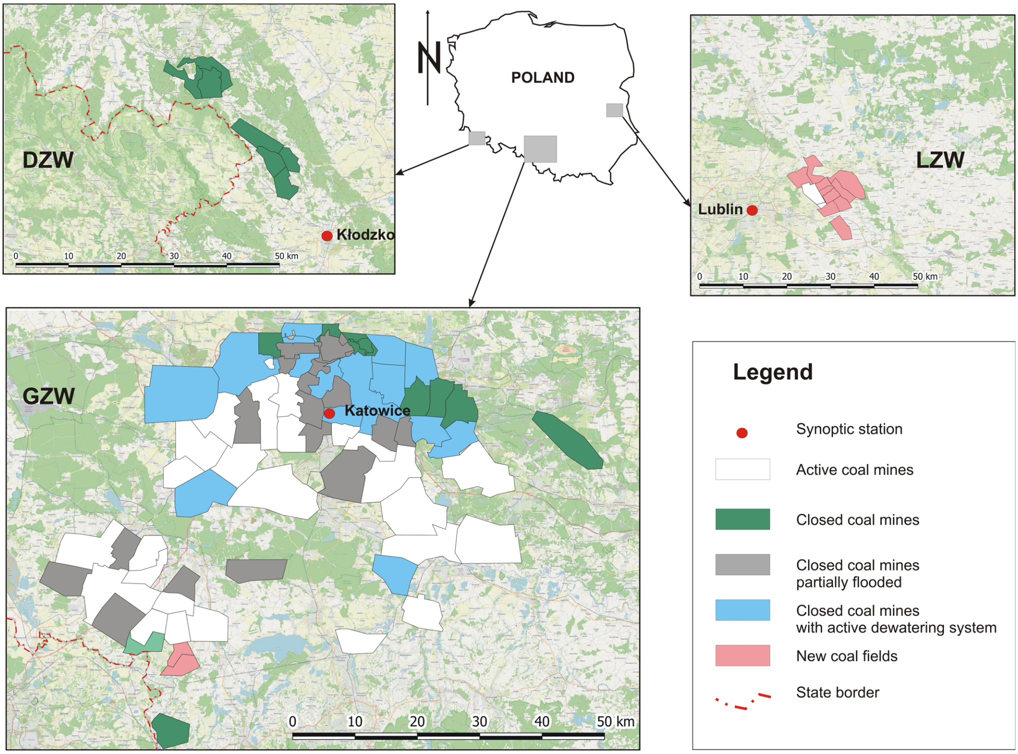

Fig. 1. Mining regions in Poland with the location of synoptic stations (location of mine fields according to Polish Geological Survey, 2020)

Emphasis should be placed on the planning and proper design of the operation actions identified as vulnerable to climate change impacts.

These activities are (a non-exhaustive list):

- dewatering of coal mines (in relation to increasing trends of precipitation),
- land reclamation issues and mining waste management (in relation to drought and heavy rainfall),
- mine shaft filling with relation to water hazard due to an increase in mine water inflows (in relation to increasing precipitation),
- operation planning taking into consideration future water production rates,
- ventilation design and changes due to atmospheric pressure drops,
- gas hazards in flooded mining areas,
- surface stability in relation to drought and heavy rainfalls (in general in active and abandoned mining areas),
- loss of productive labour hours due to an increase in high-heat days (shortening working days and increasing energy consumption for cooling),
- climate impacts on the production chain from planning to the closure.

Determination of the impacts of climate change should consider lessons learnt from previous extreme events in the mining industry. While most dangerous events are complex and caused not only by climatic influences, it is important to record previous events to identify them in particular connection with climatic conditions.

3. Case studies

Analysis of the literature and available documents revealed that in Poland there are no clearly identified incidents in underground mining caused by heavy rainfall, temperature or air pressure changes. When analysing hazardous events in underground mining, it can be assumed that some were caused directly or indirectly by those factors. However, there are no scientific publications on this topic, only information about the events themselves, where the original reason for their occurrence is not provided. Every year, the State Mining Authority in Poland publishes reports on hazards in mines (Reports, 2000-2018). One of the hazards discussed is the water hazard, which is defined as the possibility of inrush or uncontrolled inflow of water, brine, lye or water with loose material to excavations, posing a danger to the mining plant and its employees. In the years 2000-2018, eight water inrush events occurred in Poland.

In 2018, an event took place at the gypsum and anhydrite Mine “Nowy Ląd” in Niwnice (near Lwówek Śląski, in Lower Silesia) where water inrush occurred in the K-45 chamber, and the appearance of sinkholes on the surface were noted. In this case, the investigation of climatic conditions (meteorological data on precipitation) was not considered. In 2013, in the KWK “Knurow-Szczygłowice” coal mine water inrush to the excavations of coal seam 408/2 caused one serious accident and six incidents without danger to people, in terms of classification of accidents by State Mining Authority in Poland. ‘Serious accident’ means that people were severely injured, while ‘incident without danger to people’ in general relates only to equipment and facilities damage. In this case links between climatic conditions and an increase of mine water inflows were not investigated.

In 2010, two underground water hazard events were reported (State Mining Authority 2000-2018 Reports). Those events took place in an abandoned coal mine in Siemianowice where pumping systems were operating to protect active adjacent mines. On October 2th, 2010, mine water inrush, through insulating dams, occurred to the excavations at the level 321 m below ground level (bgl). The estimated volume of mine water was 8,600 m^3 and it flooded the mine workings, water galleries and the main pumping station chamber. One week later on October 9th, 2010, water from behind the three insulating dams, built-in in the main drift at the level of 321 m bgl, re-entered the workings. As a result of the water inrush, all adjacent excavations at the "Siemianowice III" shaft were flooded, including the pumping station and the main electrical facilities on this level. In this case investigations on heavy rainfall occurrence and the flood in May 2010 in the Wisła river basin (where the Siemianowice pumping station is located) were not carried out in consideration of the impact to water hazard in the Siemianowice pumping station.

Extreme events related to a water hazard due to mining works were recorded in 2007 in KWK "Pniówek" where there was an uncontrolled inflow of water with loose rock material into the shaft, which prevented evacuation of the 1000 m level via this shaft. Similarly, in 2002 at the KGHM Polska Miedź (Polish Copper Company) S.A. ZG "Rudna", a rapid outflow of water occurred during the sinking of the shaft. In 2000, water inrush occurred twice in the "Janina" coal mine and the "Nowy Ląd" underground gypsum and anhydrite mine in Niwnice.

Heavy rainfall in May 2010, caused a flood in the Upper Wisła river watershed, where the southern part of GZW is located. On 18th May 2010, the levee of a mine water pond at "Brzeszcze" coal mine was partially destroyed by river water inflow. Approximately 900 m of the levee was broken and the mine water pond was not functional for three months while reconstruction of the levee was finished (with the use of mine wastes and geomaterials to increase its tenacity).

Abandoned coal mine fields and the dewatering of mines, among other factors, are responsible for gas hazards and surface stability issues. Gas hazards were reported in the DZW (Dzieniewicz et al., 2006) and were related to monitoring of gas emissions in the areas of abandoned coal mines. The maximum measured flows of methane and carbon dioxide were 620 dm^3/m^2h and 330 dm^3/m^2h, respectively. Analysis of the results referring to the geological model of hard-coal deposits revealed that the main factor controlling the presence of coal-bed gases in the near-surface zone is the so-called "water piston effect", which is the phenomena occurring in abandoned coal mines where cessation of pumping and process of flooding inevitably disturbs migration and pressure of gases in the overburden. Recognition of both gas migration mechanisms and the dynamics of their flow towards the overburden enabled the preparation of the categorization (scale) of potential hazards encountered in the area of the DZW. Research does not indicate any direct or indirect relation to climate parameters and extreme weather events, such as changes in atmospheric pressure.

In GZW area, there are 24 shafts left for water pumping purposes and gases can flow through them hydraulically. One of them – "Gliwice II" shaft – was selected for inspection to identify changes in the emission and concentration of carbon dioxide around the shaft (Wrona et al., 2016). The tests were carried out on 28.02.2014 in the vicinity of the "Gliwice II" shaft at ground level. This day was windless and the pressure drop tendency was 0.4 hPa/h. The highest CO_2 concentration by volume was 5.00% – over 100 times more than normal in the atmosphere, whilst no methane was detected. The high concentration of CO_2 at ground level extended to about 8 m away from the shaft.

Fig. 2. Sinkhole in the former "Niwka Modrzejów" mining Area, Sosnowiec GZW Poland (Naszemiasto, 2013)

Fig. 3. Sinkhole in the former mine field of "Jan Kanty", Jaworzno GZW Poland (Polska Times, 2017)

Former minefields and areas of old shallow workings are identified in the archive documentation of the Polish State Mining Authority. A project to identify old shallow workings, as reported in (Polish State Mining Authority, 2016), found that there are 919 old mining excavations connected to the surface in DZW. In the north eastern part of GZW, where the last coal mine was closed in 2016, 685 such excavations were identified. In 2017, an inventory in Upper Silesia began, which continued through 2018; in this area there are the oldest shafts and underground galleries. The results of this inventory help to inform about potential threats related to surface deformation and they should also be useful for local spatial development plans. In relation to weather events or heavy rainfall, correlations have not been considered in published or unpublished papers or documentation.

As in other countries where underground coal mining has been closed down for many years, surface stability problems still occur and cause danger to people and properties. In Poland during the last 5 years, 12 land collapse events, some of them categorised as severe, occurred in Upper Silesia. For example, sinkholes formed in the former mining area of "Niwka Modrzejów" in Sosnowiec (areas of old shallow workings), in an urban area of Dańdowka district, which took place on 24th of June 2013 – (Naszemiasto, 2013) (Fig. 2) and in the former mining area of Jan Kanty in Jaworzno in urban area of the Podwale district, which took place on 28th of December 2017 – (Polska Times, 2017) (Fig. 3).

A shaft collapse at the Szczygłowice coal mine (Dziennik Zachodni, 2008) (Fig. 4) – in the western part of GZW, took place on 4th of September 2008. It was a severe mining event which

Fig. 4. Shaft Collapse – "Szczygłowice" Coal Mine (Dziennik Zachodni, 2008)

was investigated by the District Mining Office and identified as a building catastrophe. The shaft tower and buildings were in very poor condition, and the stability of the surface was never investigated in relation to climate and weather events.

4. Discussion and recommendations

An approach presented in this paper has revealed that complex analyses of extreme weather events, climatic conditions and severe mining events are necessary in order to find correlations. The aspects of extreme weather events affecting the functioning of the mining industry in Poland, are essential for proper preparation of mitigation and adaptation plans, taking into consideration transition process of mining industry. The potential impacts of climate change in Polish coal regions were not an area of particular interest in recent years, and determination of the impacts of climate change should consider lessons learnt from previous extreme events in the mining industry. This approach is particularly important to reduce risks for employees (severe accidents with people), infrastructure damage (shaft collapse and sinkholes in urban areas) and economic losses (unexpected costs for mining entrepreneurs). Defining further scenarios in risk assessment and the necessity of preparing a risk management plan for the mining industry in Poland is obvious and should address a wide range of mining activities, including mine closure and restructuring process.

Based on interdisciplinary studies and research, the preparation of risk management plan for the mining industry should combine the environmental impacts, associated risks and mitigation methods, in order to support the mining industry in effective adaptation to climate change. In order to follow a quantitative approach, a risk management tool as the element of risk management plan, should include climate change projections based on numerical data resulting from modelling and simulation. According to identified impacts of climate change the input data should consist of:

- safety factors for natural slopes, dumps and tailing dams under regular conditions and extreme weather events,
- admissible displacements for every case and condition analysed,
- threshold definition based on displacement water content and pore pressure for the establishment of different warning levels to assist mine authorities and operators,
- typical effects of the increased fluctuations of groundwater recharge on substance release,
- the enhanced impact range of mine water discharge on the receiving water with respect to environmental limits.

Adaptation plans for the entire mining process such as exploitation, transition and restructuring, dewatering of abandoned mines, as well as mine closure which would benefit from proper identification of climate change potential impacts on each element of mining process.

Implementation of risk management plan is expected to mitigate negative effects of climate change, in relation to safe working place conditions, economic savings, social and environmental benefits such as i.e. reducing emissions to air and water, recognition of hazards derived from reduction of slope and shaft stability. By focusing on assessing and minimising the environmental impact of extreme weather events on mining operations, providing guidance to all stakeholders on gradual and sudden impacts on operating, closed and abandoned coal mines brought about by climate change and extreme weather events is crucial. The risk management plans and risk assessment tool are one of the main goal of the project TEXMIN -*The impact of extreme weather* *events on mining activity.* The overall objective of the project is to develop an integrated management tool and monitoring strategy for reducing the vulnerability of the mining sector to extreme weather events and climate change. The tool will include climate change projections based on numerical data, resulting from modelling and simulation.

5. Conclusions

Climate change and its consequences can significantly affect the operations of the mining industry, which is particularly vulnerable for this impact being in transition process, already reducing costs and coal output and implementing pro-environmental solutions to meet the requirements of European Green Deal and EU's commitment to reduce CO_2 emission in 2050 perspective.

While many scientific papers have been devoted to the study of human impact on climate change, there is still a lack of extensive literature on the impact of these changes on industrial activities, in particular mining activities in Europe. In Poland, this problem has not yet been noticed, even though there have been many incidents in the past, the nature and time of which directly indicate a link with extreme weather events. Climate change may have both direct and indirect impacts on the mining sector. Precipitation, temperature and atmospheric pressure drops have been identified as the most important factors affecting all aspects of the mining processes, from exploration, to extraction, transport and closure. Therefore, it is necessary to develop research aimed at describing the relationships between extreme phenomena and the functioning of the mining industry as well as further actions aimed at limiting the negative impact of climate change:

- complex analyses of extreme weather and severe mining events to identify climate change potential impacts on mining process,
- preparation of mitigation and adaptation plans for both operating mines and closed ones or in transition process,
- risk management plan based on risk assessment taking into account further scenarios,
- risk management tool as the element of risk management plan including climate change projections and results from modelling and simulation.

In this paper we have presented the first step in investigations which are focused on the determination of the most important factors related to climate change which are increased precipitation and sudden and heavy rainfall, atmospheric pressure drops and increased temperature. The climate change impacts on mining activity both active and under restructuring will require the preparation of more comprehensive tools and monitoring strategies. In accordance to the presented literature review and own study, it is very important to identify, define and prepare the 'climate change adaptation plan' for the coal industry in Poland.

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