DELIVERABLE D2.1.

REPORT ON PHYSICAL AND CHEMICAL IMPACTS DUE TO CHANGES IN PRECIPITATION – SUMMARY

CHANGES IN DISCHARGE AND COMPOSITION OF SURFACE RUNOFF WATER - SUMMARY OF RESULTS

The first part of the document analyses the changes in discharge and composition of surface runoff water by analyzing the geochemistry of rainfall and water fluxes associated with coal spoil tips in each region (UK, Poland and Greece) (works developed by University of Exeter, SUT and CERTH).

The UK spoil heap study investigates and collects this geochemical data, and also achieves the analysis of solid material, which may have the potential to affect water flows from soil heaps. Due to the problems associated with COVID 19, it has not been possible to work in collaboration with The Coal Authority, however the work has been carried out to meet the required objectives.

Water flow data has been obtained from the chemical analysis of 12 spoil heaps in the UK. In most cases this water is untreated, except in 2 cases where exists a treatment plant, allowing a comparison to be made. Samples of solid materials have also been analysed, which will allow the improvement of the models needed for the WP3 and WP4 work, as well as a resource for future research.

In Poland, the Libiąż coal waste dump, located in the south of the country, was selected. This study evaluated the chemical and phase composition of the deposited waste, the effect of climate change (mainly higher and lower precipitation) on the intensity of the impact of coal waste disposal on groundwater, the influence of various chemical and physical parameters in batch and column tests, and in the case of a column test additionally at different flow rates, on the chemical and physico-chemical state of the leachate and to propose how to prevent the release of chemicals from the waste dumps into the environment as a result of acid mine drainage.

The samples studied result from a mixture of mining waste from various coal processing processes. Analyses indicate the possibility of heavy metals and sulphates being released into the aquatic environment in case of contact with a large amount of water due to excessive precipitation, due to the significant amounts of sulphide minerals found in some samples.

The groundwater levels in the vicinity of the dump, physicochemical parameters and chemical composition of groundwater (pH, concentrations of Cu, Ni, Pb, Cd, Fe, Zn and concentrations of SO42-, Cl-, Cr(VI)) and meteorological data for the Katowice area from 2002 to 2020 have also been studied. Katowice is located about 20 km from the assessed landfill.

For this study area it is observed that periods of drought occur mainly in spring, while periods of excessive short-term precipitation in summer. The period from 2007 to 2010 was one of excessive precipitation, followed by a period of fairly dry years until 2016. These periods of increased precipitation affected groundwater compaction due to leachate from waste dump, requiring remediation works.

The chemical composition of the leachate after leaching tests (batch tests) of waste taken from the disposal site, and the leachate generated by different flow rates of rainwater through the column in which the waste collected from the waste dump was placed have also been analysed. The results show that in the periods of highest precipitation intensity in a short time, the runoff water does not have much contact with the waste material. However, the mobilisation of fine materials constitutes another important source of contamination with substances such as spent metals. In longer, but less intense precipitation periods, pollutants are leached out directly from the waste material, resulting in considerable contamination of the groundwater.

Finally, the removal of Cu(II) and Zn(II) from synthetic mine drainage is analysed to determine a treatment process. The nZVI has a better removal efficiency for Cu(II) than for Zn(II). This material seems quite promising for the removal of metals from leachate and contaminated groundwater from mine waste dumps.

The major lignite mining complex of Greece was used to obtain spoil samples and analyze them for the current Task. This complex is located near the Ptolemais city in northwest Greece and is named the Western Macedonia Lignite Centre. The same area has also been used in the previous work of TEXMIN for the baseline climatic report, the climatic projections, and as the base location for modelling purposes. Several spoil tips exist in this area, and specific locations - where water flows from spoil tips are gathered - were identified by the mine owner (the Public Power Corporation). Three water samples were collected and analyzed to investigate the geochemical composition of the rain, and the associated water flows from Greek lignite spoil tips. The first sampling was collected in December, after a day of heavy precipitation (about 14mm). The second one took place in March, after a dry month without precipitation and dry weather; this sample serves as the baseline. The third one was collected in April after three days of heavy precipitation with an average daily rainfall level of 10 to 14mm. For the three samples, on-site measures were made for the fundamental properties of the water and were further complemented by laboratory analysis.

The measurements of the three samplings included dissolved oxygen, pH, conductivity and major metal and trace elements. The highest permissible values in drinking water according to 98/83/EU were used as reference. In the present study of Greek spoil tips, the pH and the dissolved oxygen are not significantly affected by heavy rain and do not show significant fluctuations. On the other hand, the measured conductivity presented quite large fluctuations among the three samplings; a safe conclusion cannot be drawn for this inconsistency. Moreover, fluctuations were presented in sulphate concentration, and concentrations of Silicon, Sodium and Magnesium were slightly increased after heavy rain precipitation and

subsequently decreased after the dry period. On the other hand, Nickel, Lead and Iron concentrations are increased after the dry period and subsequently decreased after the heavy rainfall events. Finally, the concentrations of heavy metals, even though they fluctuated among rain precipitation and dry periods, in almost all cases remained within the legislated limits of the 98/83 EU directive for water suitable for human consumption. Only copper concentration was slightly over the limit.

Overall, CERTH investigated the geochemical composition of the rainfall and water flows from coal spoil tips in Western Macedonia Lignite Centre. Three samples were used, with two of them being collected after heavy rainfall days and another one in drought weather conditions. The comparison does not provide a clear image or clear trends concerning how rainfall affects the composition of surface runoff water. A tentative conclusion based on the current measurements is that weather conditions in the present case do not significantly affect the composition of the surface runoff water.

In respect of flooding events from mine spoil tips on abandoned mines, it is noted that these events are not very frequent in the UK, with a total of 8 events in the last 19 years. Although it could be that the effects of climate change may have been one of the causes, it is more likely that the absence of records is the main cause.

Of those events, most occurred under continuous episodes of intense rainfall, where a high saturation of the soil occurred. Due to this saturation, runoff occurs, which is the main cause of floods. Of all the cases analysed, only one event in the UK results from runoff from a soil heap, which will allow the comparison of the results of the numerical model to be developed in task 3.1, with the intention of performing a correct calibration by accessing historical data.

CHANGES IN DISCHARGE AND COMPOSITION OF MINEWATER - SUMMARY OF RESULTS

The second part of this deliverable D2.1 researches how the changes in discharge and composition of surface runoff water affects different coal mining areas in Europe (works developed by DMT and GIG).

Three research sites in Germany, three in Poland and one in Spain are studied in order to collect mine water samples. The specific properties of each sample depend on the selected site, but based on the results it can be seen that mine water in the deep coal mining industry is only slightly affected by changes in precipitation. In the most extreme cases, such as in karst areas where the permeability of the ground layers is very high, only a sudden increase in inflow can be a hazard.

The amount of seepage that occurs in a mine affects the composition of the mine water, depending on the individual substances present and the characteristics of each location. The coal layers being mined in Europe contain mainly pyrite, so that increases in seepage after a long period of drought, above-average increasing concentrations are possible.

In the analysed cases where the mine water remains far below the surface, the seepage water mixes with other inflows and decreases in concentration - this dilution, however, leads to an increase of substances in the mine water. Infiltration can also occur independently of other inflows. In this case, basic substances such as chloride or potassium will be mobilised from the mine water.

Climate change that may affect surface and mine water must be considered in conjunction with the discharge into the receiving water. Due to this coupling the risks and effects of climate change may appear.

STABILITY OF MINE WORKINGS AND SURFACE STRUCTURES – SUMMARY OF RESULTS

The last third part of the deliverable studies the stability of mine workings and surface structures. The first case presented study The Most Coal Basin, known for its largest Czech brown coal deposit (works developed by VUHU). The precipitation has been evaluated from 1961 to 2019. For this area and period no relevant damage to mine structures due to climate change has been observed. In 2018 a longer than usual drought period caused a significant impact on the forest stand, leading to the occurrence of landslides. However, these did not affect any mining workings. Therefore, the vegetation of the area and its resistance to heat and drought have been analysed for subsequent remediation measures. After the chemical analysis of hydrogenetic rocks (gypsum), which are a problem in the western part of Most Basin, it is recommended the application of restoration substrates suitable for mild acidification after results evaluation, with the consequent lowering of pH values.

Regarding the effect of changes in precipitation on tailing dams (works developed by SUB), a general study of these has been made, as well as an assessment of the most probable failures due to extreme climatic events. For the specific case of Spain, only the Aznalcóllar mine disaster is well documented, but it is difficult to relate this event to an unusual precipitation episode. For this reason, the case of the Santa Fonte tailing dam (Portugal) has also been evaluated, with a similar climate to Spain, where a period of high rainfall did play a role in the rupture of the dam. As for the formation of sinkhole effect due to the variation of the groundwater table, no documented cases have been found where a direct relationship has been established (nevertheless, there are numerous cases of sinkhole formation due to the existence of shallow ground workings). It would therefore be interesting to monitor these underground workings to study this relationship.

For the development of the numerical modelling to be carried out in WP3, pore pressure and water table data have been accessed at the Cobre Las Cruces mine tailing dam from 2006 (due to data availability) to the present. These data have been compared with the precipitation of the area, case of the climate study carried out in WP1. An analysis of the variation in pore pressure due to changes in precipitation has been carried out, trying to differentiate them with the extractive process itself. Despite not being a coal mine, the tailing dam study is equally valid. It should be noted that in Spain there are currently no tailing dams associated with coal mining, and there are no data available, so the data obtained will allow a more appropriate

basis to be established for the numerical models, in which the parameters of the tailings themselves will be modified to resemble those derived from the coal extraction process.

The third case study analyses two slopes of the coal waste dump at ZG Janina TAURON Wydobycie S.A. in Poland (works developed by SUT). In order to evaluate the selected slopes under the influence of precipitation, a total of 3 measurement sessions have been carried out.

Two methods of analysis were used: Low-altitude aerial photogrammetry (LAAP) using an unmanned aerial vehicle (UAV), and 3D terrestrial laser scanning (TLS), obtaining a surface model. In addition, infrared thermography (IRT) has been used to determine the surface temperature; thermometry technique to measure the internal temperature of the landfill; measurement of gases (O2, CO2, CO, CH4) in the atmosphere inside the landfill. All the data obtained have been converted into point clouds and 3D models.

As a result of all the measurements carried out, an important erosion process is observed due to the transport of material coming from the upper part due to precipitation. Significant gullies are observed due to the flow of rainwater, reaching a depth of 1.6m. This effect is aggravated by the absence of biological cover, poor compaction of the material, and poor drainage system in combination with heavy rainfall events.

The last case of this section studies how changes in precipitation affect sealed and backfilled shafts, analysing six different locations in the southern part of Poland. The work done by GIG, TWD and SRK allowed to constitute the robust base for further analysis that are mainly aimed to develop two pilot installations for shaft liquidation and waste dump slope stability.

Considering liquidated shafts SRK proposed to analyse six cases with relatively thick layer of quaternary formations that are especially vulnerable when analysing the impact of extreme weather events. When choosing the sites also the reliability and completeness of available data on shaft structure was analysed. Moreover the shaft liquidation plan need to be in line with project TEXMIN timeline. In the end, after deep analysis of geological conditions, shaft construction data and backfilling options, it was decided to apply new liquidation method at Shaft Głowacki. SRK was eager to apply enhanced design procedure (WP3 and WP4) due following reasons:

- failure of liquidation process of neighbouring Shaft Kościuszko that was caused by uncontrollable water flow;
- the proximity of active mine “ROW” that needed to be protected against water inrush;
- relatively big number of shaft connections with horizontal workings.

With respect to waste dump, the monitoring work conducted by SUT and TWD together with analysis and processing of available geological and geomechanical data allowed to develop fully parametrised numerical model that will be used to analyse slope stability under influence of extreme weather events.