TEXMIN D2.2 Summary
Physical Impacts Due to Changes in Temperature

It is widely acknowledged that climate change is occurring and that this will affect the entire planet. Although there are many aspects to climate change, one of these is an overall increase in temperature and this has been the particular aspect of study in T2.2 and hence it is the subject of D2.2. In particular, we have looked at how increasing temperatures in the European coal mining districts and the former coal mining districts, is expected to influence working, closed and abandoned mines.

First, the effect of increased temperatures on efforts to rehabilitate closed mines (i.e. those that are under care and maintenance) and abandoned mines has been studied. As well as a general study of this subject – which has concentrated on the most challenging aspects of revegetation of spoil heaps and, where appropriate, the construction of wetlands – we have conducted a particular study of the following two subjects: (1) the negative effect to rehabilitation efforts caused by the effect of climate change on biodiversity, and (2) the effect of increasing temperatures on vector disease shift. This latter point refers to the northern migration of vectors (an epidemiological term for a living organism that carries a pathogen, i.e. a disease) and, in particular, malaria carrying mosquitoes which could thrive in restored or created wetlands in an increased temperature scenario.

Second, we have studied the impact of increasing temperatures on gas emissions from abandoned coal mines through theoretical analysis, in situ measurements and numerical simulations. Theory states that the higher frequency of advection of warm air masses may favour the occurrence of the phenomenon of thermal buoyancy, thereby increasing the movement of mine gases from the rock mass to the surface. The above conclusion was confirmed during 12 measurement series of mine gas emissions from an abandoned shaft during spring, summer and autumn. The four most characteristic cases were selected for analysis, one of them including an extreme weather event – an upcoming storm. The results confirm that the large temperature difference between the atmosphere and the emitted gases contributes to increased gas emissions from the closed mine through the shaft studied. In addition, the results were used to validate the numerical model of the process occurring in this particular shaft. The model was built using Ansys Fluent software. A numerical model was adopted without pressure change, only temperature variations being investigated. Four test cases were prepared in which there is a two- or five-degrees Celsius temperature change in two hours. The change was assumed in two sub-variants – temperature rise and fall. The results confirm that hot mass advection can contribute to accelerating the process of gas emissions from underground voids through abandoned shafts (not filled with backfilling material). The variation is not significant, therefore temperature increases should only be treated as an accelerating factor. Analysing the negative change in temperature shows that the advection of the cool air mass is a factor that causes air to flow into underground voids. Thus, in the case of a dominant downward trend in atmospheric pressure, such a case will slightly inhibit gas emissions.

1 REHABILITATION

UNEXE studied the effect of increased temperatures on efforts to rehabilitated closed mines (i.e. those that are under care and maintenance) and abandoned mines (i.e. those that are not expected to re-open). In addition to investigating various general issues relating to rehabilitation, the potential for medium/long term changes in biodiversity and vector disease shift have also been studied as described later. Note that the reference in the task description in the Technical Annex to arid mining regions was the result of a clerical error and it was always intended to include a broader selection in climatic regions.

Before researching certain specific elements of the rehabilitation process, the subject of human factors was considered. In particular, the increased risk to staff involved in the rehabilitation work due to increasing temperatures was investigated, and preventative measures aimed at ensuring the health and safety of staff were identified. VUHU specifically considered this topic from the point of view of its own mining activity and for Central Europe more generally. They considered that the documented increase in temperature and the likely occurrence of dry periods in terms of cost and safety of work are rather favourable to their own mines. However, assessing the human health consequences of climate change is still quite problematic as most human health disorders are caused by several factors and take place against the background of economic, social, demographic and overall changes in the environment and lifestyle. Evidence to date suggests that the main negative health effects of climate change in Central Europe may be related to changes in heat stress. This factor is very important during the work in conditions of open pit mines.

Rehabilitation involves reverting a mine to its original state prior to the commencement of mining or, if that isn't possible or economical, transforming the region into a natural-looking area that blends into the surrounding region. Alternatively, it could involve making the area suitable for other purposes such as forestry, agriculture, industry, business, housing, or tourism. The actions involved in rehabilitation might involve: (1) demolition of surface buildings or their restoration and preservation for industrial or business use, or for industrial archaeology or tourism purposes, (2) filling or capping of shafts, (3) forestation or other vegetation or cultivation of areas previously occupied by mine buildings, access roads etc., (4) rehabilitation of spoil heaps, (5) filling in of tailings ponds, or conversion of such ponds, and other depressions into wetland habitats, and (6) restoration of wetlands that were present before the mining activity or creating new wetlands. Case studies of successful rehabilitation exercises were collected while studying this subject.

The aspects of spoil heap rehabilitation and wetland creation or restoration were studied in detail, because of the particular potential effect of rising temperatures on these actions. In each case, the aims and benefits of the restoration process were considered, with some reference to the process involved, before investigating the impact of rising temperatures and methods of mitigating these effects.

Wetlands for Minewater Treatment in the Pelenna Valley (EA R&D Technical Report P2-181/TR)

2 BIODIVERSITY CHANGES

An overview of this topic, by UNEXE, related mostly to the two main areas of mine rehabilitation already discussed, i.e. the remediation of spoil heaps, and the creation or management of wetlands. First, the potential effect on biological species – namely species migration and species extinction – were studied. Then, methods of mitigating these effects were researched. This involves setting realistic objectives, making the correct choice of species (plant species in the case of spoil heaps and wetlands, also animal species in the case of wetlands) in the rehabilitation process, and monitoring on a continual basis. The importance of obtaining expert guidance – often beyond the capabilities of mine operators – was noted. This work included an extensive literature search, with a full list of references appearing in the deliverable report.

This overview was followed up CERTH's work, which was approached through a literature review, and which focused on the effect of temperature change on biodiversity, with particular emphasis on Greek mining areas. Mining activities impact the environment significantly and therefore, affect biodiversity through physical pollution. A portion of land and its biodiversity has to be removed until material extraction is complete. Mining activities also include groundwater consumption and discharge corresponding to aquifer drawdown, erosion, dust/aerosol emissions and even sound and light pollution. Furthermore, they are responsible for chemical pollution from heavy metals, soluble salts, even cyanide and mercury. These conditions impact spatial biodiversity, and only a few, tolerant species can survive.

The lignite basin of western Macedonia in Greece has native deciduous oak vegetation. According to the HORVAT vegetation classification of south-east Europe, the basin is also classified as Quercetum confertae growth zone, of the Quercetum confertae and Quercetalia confertae paramediterranean vegetation zone. Between these zones, the climate turns from Mediterranean to continental with harsh winters and dry seasons. Nowadays, the region's flora (mainly oak populations) and fauna are limited due to anthropogenic factors (mining, agriculture) and restricted to a few surrounding areas of the basins, mostly rocky mountains. Additionally, overgrazing and illegal lumbering contributes to the further degradation of the ecosystem. Nevertheless, the mining activities have the most significant impact on the ecosystem due to (1) extensive deforestation, (2) fauna eviction as a result of intense human activities and destruction of their natural habitat (where they find shelter and food), (3) low variation of flora species in reforested areas that result in decreased biodiversity, (4) fly ash deposition that increases the concentration of heavy metals and radionuclides, leading to bioaccumulation of these elements, and (5) contaminated water use in agriculture and livestock contributing to the bioaccumulation effect.

The mining sector, its long-term economic viability, and land reclamation processes are vulnerable to climate change due to their dependence on the natural environment. Climate change and specifically, temperature changes are essential factors to be considered before mine rehabilitation. Prolonged dry seasons, high water precipitation, forest fires, and extreme weather phenomena severely impact the ecosystem. The first task in mine rehabilitation is the stabilisation and establishment of vegetation cover. Other tasks aim at ecosystem restoration so that animals, plant communities and effective functioning of ecological processes (e.g. soil formation, nutrient cycle) are re-established. Therefore the selected species for the re-establishment of vegetation have to be climate tolerant in order for the resulting ecosystem to be resilient to natural disturbance, fire and weed invasion; this sustainable integration concept is commonly referred to as "future-proofing".

The common practice in mine rehabilitation is the exclusive use of native species, under the premise of better adaptation to the local environment and the provision of more suitable habitat. However, the introduction of a wide variety of plant species at the early stages of site rehabilitation, and not a low variety of coloniser species, will improve the ecosystem's ability to adapt to future changes. Therefore a balanced ratio has to be achieved between the use of local species and the introduction of new species to improve the resulting ecosystem's adaptive ability. Before any strategic planning, the dominant physicochemical edaphic factors (pH, organic matter quantity/quality, and mineralogy) have to be studied to determine this introduction of new species.

VUHU's research, with particular reference to Czechia, has been in the field of selection of optimum research areas with different soil properties and different morphology. The main localities were the slopes of Most Lake (optimum brown clays, Radovesice internal dump (sandy clays, application of fertilizable rocks), Střimice internal dump (phytotoxic coaly sands), and Libouš internal dump (brown clays with salt occurrence – primarily gypsum). The next steps were preparing a database of the main pedological properties of soils including new soil analyses, preparing of a list of the development of the loss of seedlings in these localities, and conducting research into the development of biodiversity in areas retained for natural succession.

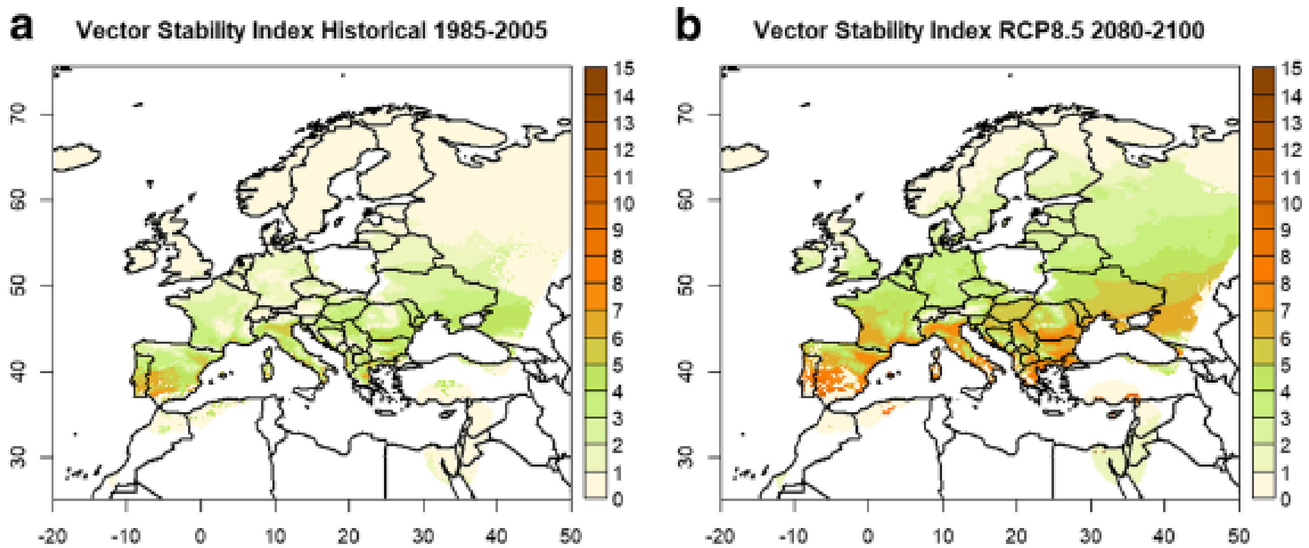
Development trends of climatological characteristics and the more frequent occurrence of extreme weather events are already reflected in changes in the water regime, in agriculture and forestry, and partly affect the health of the population. Even in the short term, a further increase in the negative impact on individual components of the natural environment can be expected, and relatively new impacts on the energy sector, recreational opportunities and tourism, as well as the overall well-being of the population, should be expected. The Most Basin area is known as a brown coal deposit and its wider surroundings are a very important industrial region. Overall, it is a dry and warm area within the Czech Republic, indeed extreme damage affected by the climate has not been recorded here in the evaluated period.

The further development of climate change will affect biodiversity from individual genes to the entire landscape. Among the most vulnerable ecosystems in Czechia are mountain ecosystems and ecosystems formed by the remnants of the original grasslands. The changes will be most pronounced in ecosystems above the shifting upper forest boundary, where vulnerability is exacerbated by their relatively small size. Species of wild flora and fauna that are closely linked to specific habitats will be most at risk. On the contrary, typically thermophilic species can inhabit most of the territory. The natural reaction of plants and animals will be to move them to areas where they will find a more suitable environment for their existence (higher altitudes, more northern locations) and will thus be able to adapt to new conditions. If they do not find suitable conditions, then there is a risk of their extinction (e.g. about one tenth of the monitored plant species). About one-fifth of plant species can adapt quickly and efficiently to a changing climate. The changes will encourage the spread of non-native invasive species and successful species will be forced to face new, hitherto unknown competitors.

3 VECTOR DISEASE SHIFT

A vector disease is a disease that is spread from human to human, or from an animal to a human, via another agent, the vector. This topic was studied by UNEXE.

Spread by mosquitoes, malaria is the most widespread vector disease, accounting for far more deaths than all other vector diseases combined. It has been suggested that it will be the disease most affected by global warming, and that a return of indigenous malaria in the UK and other northern European countries is feasible. It was, therefore, the primary focus of this element of work.



Modelled Spread of Malarial Region in Europe (DOI: 10.1186/s13071-018-3278-6)

While recognising the benefits of wetlands as part of a rehabilitation, it is noted that areas of standing water play a major role in attracting mosquitoes. For this reason, in studying mitigation measures, significant attention was given to preventing unintentional areas of stagnant water, and protecting wetlands from vector migration. In particular, measures related to ponds present during mining operations, depressions that could become filled with water, and wetlands created deliberately as part of the rehabilitation process were considered. Again, this work included an extensive literature search, with a full list of references appearing in the deliverable report.

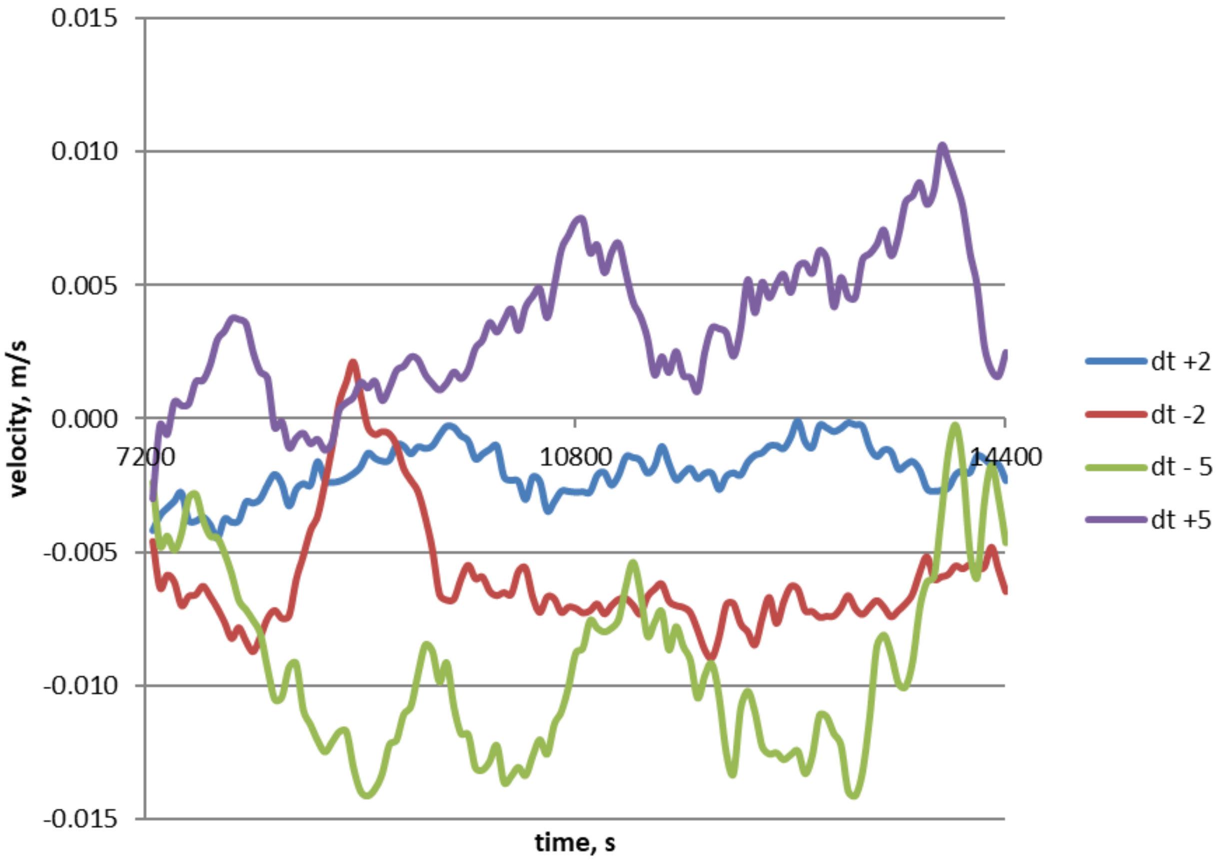
4 GAS EMISSIONS

SUT studied the impact of increasing temperatures on gas emissions from abandoned coal mines. The studies were divided into the following steps: theoretical analysis, *in situ* measurements and numerical simulations. Theory states that higher frequencies of advection of warm air masses may favour the occurrence of the phenomenon of thermal buoyancy, favouring the movement of mine gases from the rock mass to the surface. The above conclusion was confirmed during one preliminary and 12 specific measuring series above a shaft referred to as II, and which cannot be identified because of a confidentiality agreement. The series covered the spring, summer, autumn and winter seasons. The start was delayed until 11th May due to the COVID-19 lockdown (March-April 2020). The four most characteristic cases were selected for analysis, one of them including an extreme weather event, namely an upcoming storm.

The results confirmed that the large temperature difference between the atmosphere and the emitted gases contributes to increased gas emissions from the closed mine through shaft II. On 22nd August 2020 before the advent of the atmospheric front, the air temperature reached 35°C, and the temperature of the emitted gases exceeded 25°C. Before the advent of the atmospheric front, i.e. from 14:00 to 17:00., the CO_2 concentration increased to 2.37% vol., and the oxygen concentration dropped to 18.4% vol. At the same time, the highest temperature difference between the environment and gases – specifically +12°C – was noted. Concluding, even a relatively low pressure drop intensity caused a concentration of CO_2 equal to 2.37% because of the high temperature difference between the atmosphere and the gases. Conversely – on 23rd May 2020, a negative difference in temperature between air and gas was recorded for the entire period of measurements (from 09:00 to 17:00). This difference ranged from the value of -2.5°C at 09:00 to -0.6°C at 11:00. The average hourly intensity of the pressure drop wasn't relatively low (0.34 hPa/h), but the ambient temperature varied from 15.2°C to 16.3°C when the gas temperature varied from 16.6°C to 18.1°C. This resulted in a low value of CO_2 concentration and a high value of oxygen in the emitted gases, a maximum, respectively of 0.48% vol, and 20.1% vol. The maximum outflow velocity on that day was also low and did not exceed 0.51 m/s.

As the next step, the results were used to validate the numerical model of the process occurring in this particular shaft. The model was built using Ansys Fluent software. A numerical model was adopted without pressure change, only temperature variations being under investigation. Four test cases were prepared. They compromised the variants where there are two- and five-degree temperature changes in two hours. The change was considered in two sub-variants – temperature rise and fall.

The results confirmed that hot mass advection can contribute to accelerating the process of gas emissions from underground voids through abandoned shafts (not filled with backfilling material). The variation is not significant, therefore temperature increases should only be treated as an accelerating factor. Analysing the negative change in temperature, it can be seen that the advection of the cool air mass is a factor that causes air to flow into underground voids. Thus, in the case of a dominant downward trend in atmospheric pressure, such a case will slightly inhibit gas emissions.



Emissions Velocity from a Shaft for Different Variations of Air Temperature

VUHU reported that in the Czech Republic, the Most Basin is a monitored area with the largest brown coal deposits and one of the most burdened by poor air quality. Air pollutants parameters of the concentration of suspended particles fraction PM_{10} and $PM_{2,5}$, plus concentrations of SO_2, NO_2, NO, NO_X and O_3 were studied. According to the evaluated data, the concentration of most air pollutants is gradually decreasing. The main reason for the decrease in concentration is the ecological measures implemented. Typically, there has been a significant decrease in PM_{10} and $PM_{2.5}$ concentrations, which is caused by the dust-decreasing measures of open pit mines. The desulphurization of power plants and technical measures in industrial plants are also important, and the implementation of these measures can overlap climatic and other influences. An exception is the concentration of ozone, which has been increasing in recent years. In this case, a gradual increase in temperature is a likely cause.

5 SUMMARY

The effect of increased temperatures on rehabilitating closed and abandoned mines was studied. The study considered the effects of higher temperatures on staff involved in rehabilitation, with particular reference to the most challenging aspects of revegetation of spoil heaps and the construction or rehabilitation of wetlands. This was followed up by considering two specific related subjects that need to be considered in a future climate environment. First, we looked at effect of climate change on biodiversity, and suggested means by which any negative impacts could be alleviated. Second, we researched the effect of increasing temperatures on vector disease shift. This refers to the northern migration of vectors – an epidemiological term for a living organism that carries a pathogen, i.e. a disease – and, in particular, malaria carrying mosquitoes which could thrive in wetlands in an increased temperature scenario. The scale of the threat was considered, and mitigation measures were proposed.

A study was made of the impact of future temperature changes on gas emissions from mines. This involved a theoretical analysis, making practical measurements at a shaft, and numerical simulations. The results confirm that hot mass advection can contribute to accelerating the process of gas emissions from underground voids through abandoned shafts (not filled with backfilling material). The variation is not significant, therefore temperature increases should only be treated as an accelerating factor. Analysing negative changes in temperature shows that the advection of the cool air mass is a factor that causes air to flow into underground voids. Thus, in the case of a dominant downward trend in atmospheric pressure, such a case will slightly inhibit gas emissions.