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Assessment of the Use of Secondary Energy Products in the Field of Reclamation with Environmental Impact

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Abstract. This article deals with the use of secondary energy products in the area of reclamation and, within this context also with the environmental impacts of these secondary energy products (next referred to as SEPs). The bases for environmental impact assessment and possible use for reclamation have been provided the authors data, knowledge, observations and experiences gained with in the preparation and partial reclamation of the area Ervěnice. The authors also took into account the properties of the secondary energy products determined for the technical part of reclamation and also into the data obtained in the framework of geological and hydro geological survey, groundwater monitoring and sediment monitoring of deposited secondary energy products, mine report and historical records concerning the completed deepwater mining and subsequent surface mining. The research will analyse the influence of SEPs on underground and surface water, the impact of dustiness on nearby urban agglomerations as well as adjacent industrial plants.

1. Introduction

Heat is one of the basic energies needed for life. It can be secured from different sources. One of the most efficient methods is the central production of thermal energy in the heat generation plants in the combined generation of electricity and heat (next referred to as CGEH). The most used feedstock of this combustion process is brown coal.

As secondary products of the coal-fired process in large power and heat sources generate ash products after combustion. Nowadays, these ashes, also called secondary energy products, are to be exploited as much as possible for economic as well as industrial reasons. Secondary energy products are therefore subject to assessment for their possible usability and subsequently, if strict conditions are met, certified for use as e.g. a product suitable for embankments and backfills or as a basis for communication or for consolidation of hoppers and other sloping terrains, [1, 2, 3, 4].

The main objective of this article is to assess the impact of the use of secondary energy products from the Komořany heating plant and the conditions for their use in reclamation of wasteland in the former Ervěnice area. The site in question is located near the 1st class road No. 13 (E442), industrial sites, siding and also ČSA quarry. The area is part of the Mostecka brown coal basin and lies about 6 km northwest of the town of Most, about 11 km southwest of Litvínov and about 9 km from Jirkov.

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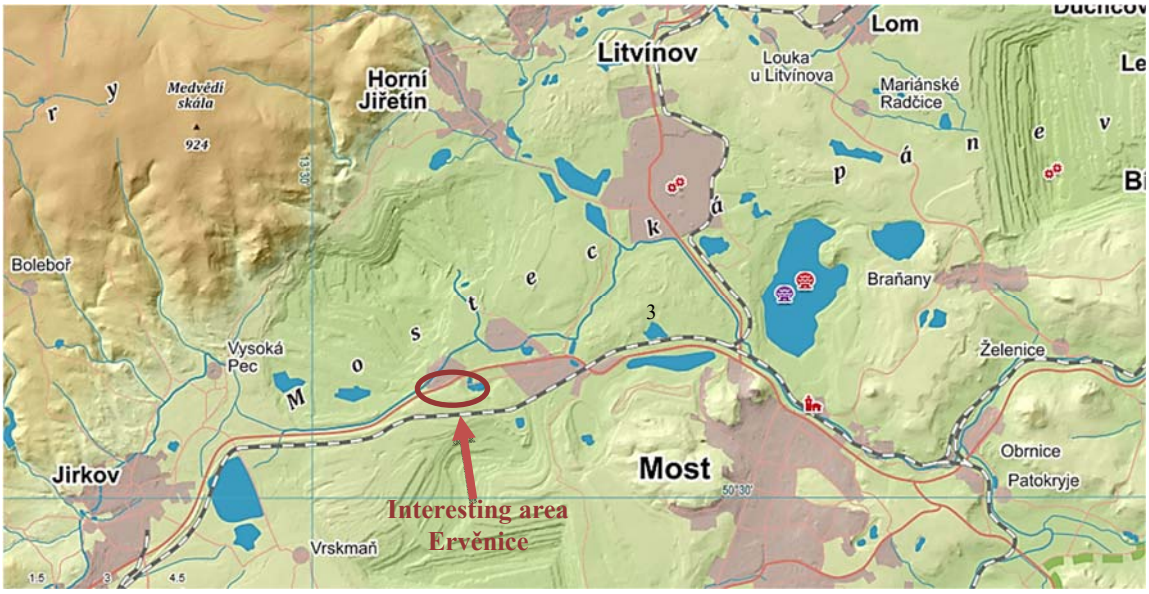


Figure 1. Location of interest site in North Bohemian brown coal basin, [5]

2. Secondary energy products

The combined heat and power technology is based in principle on the chain of chemical energy transformations contained in the fuel to thermal, mechanical and electrical energy. Heat is obtained by combustion of fuel in high-pressure steam boilers. Combustion of solid fuel produces solid residues, i.e. products after combustion or also secondary energy products that are modified and further treated as products for further use. These products are now called granulate or additive granulate. It is a humid mixture of fly ash captured from flue gas by different separation systems and bottom ash discharged from the combustion chamber of the boiler, which is enriched with lime, limestone according to the specific combustion method.

Additive granulate is certified building product (next referred to as CBP) intended for separate, combined or composite foundations in the construction of internal and external dredges of surface mines, for the construction of embankments and backfills as part of the smoothing of the consequences of mining activity carried out by the technological procedures established and approved in the plans of the opening, preparation and mining, or as a subsurface for roads or base construction structures.

Such certified construction product is listed in annex no. 2, list of products 9, order no. 14 according to government regulation no. 163/2002 cod., as amended by government order no. 312/2005 cod. - as "Granulate and additive granulate in surface mining dumps for embankments and dykes in mining operations". In accordance with the above legal regulation, the manufacturer ensures a production control system in accordance with the requirements of §5 section 2 point (c) of that regulation, [2, 6].

In the framework of further research, the utility of SEPs produced in the Komořany heating plant will be assessed, where mainly brown coal from the basin of Most is burned in the high pressure steam boilers. With fluid combustion technology, limestone is also fed into the combustion chamber together with the fuel, so the secondary energy products are already directly enriched with limestone, [7]. The result of the whole technological processing is in this case the additive granulates composed of a mixture of fly ash and ash humidified at 36.7% ± 5% by volume humidity. The annual production of the additive granulate is about 450,000 tons in Komořany heating plant.

3. Utilization of secondary energy products

The issue of the use of SEPs arising from flue-gas combustion in the Komořany heating plant in the area of reclamation and construction with environmental impact in the vicinity of residential units must be dealt with in a broader context.

Secondary energy products from fluidized combustion can be used in several ways. The first step is to return the material back to the surface mines and use it as part of the mining process, for example, to build access roads, consolidate slopes, etc. In the mining industry, SEPs are also used for the technical reclamation of internal dumps and, if necessary, such as offsetting terrain inequalities.

Another suitable and certified way is to use in the construction industry where they are used for road construction, backfilling in the foundation structures of new buildings or, for example, flood protection dikes. It is used also for technical reclamation areas outside the mining area and the last possibility is the use of this inert material to separate and consolidate individual layers within the landfill of waste.

All of the above ways of use are judged from the environmental, economic and commercial aspect.

3.1. Impact on underground and surface water

In general, it is always necessary to assess the reclamation of SEPs in terms of the state and the quantity of underground and surface water in the area under consideration. Some types of CBPs made from SEPs are suitable for watertight solving of the space. The surface water in the reclaimed space can be led into a retention area or into a suitable waterway. Groundwater can be affected by the increased pressure of the overlay layers and thus extruded to other places where it has not yet been found. This phenomenon is likely to occur especially in places where aquifers are found. It is therefore appropriate to assess the geological and hydrological structure of the substrate layers and to design appropriate monitoring wells for monitoring the quality of the water, including any leachate and drainage conditions in the area.

3.2. Impact of dust and noise on urban agglomerations and industrial areas

If SEPs are used for one of the most natural activities such as reclamation of surface coal extraction or technical reclamation of industrially used areas, the dust and noise level increases at the time of the works. It is a temporary influence, it is caused by mechanization, manipulation with the SEPs material and it is finished after the completion of these works.

4. Hydrological a hydrogeological condition in the area

In order to assess the suitability of SEPs for reclamation of the area, it is necessary to consider the overall characteristics of hydrological and hydrogeological conditions in the area. It is important knowledge of the shapes and internal structure of bodies that are located in the given area and which significantly influence the behaviour of groundwater. Equally important is the basic characteristics of the rocks, including in particular the mineral composition, which affects the groundwater chemistry itself. From the hydrogeological aspect, it is important for the drained collectors of the underlying and intermediate sand.

For most of the magmatites found in the subsoil of the North Bohemian Brown Coal Basin (NBBCB), the so-called prototectonics is a characteristic feature. By arranging the structural elements at a time when the magma was still fluid or plastic-viscous, linear or parallel structures emerged.

Subsequently, the tectonic forces on magma produced regular fracture systems that can be divided into three types: lateral cracks (often openand filled with hydrothermal products), longitudinal

fractures (according to them the rock is easy to split) and bottom fractures (are in the direction of the rock layers), [7].

The occurrence of sedimentation in the area was associated with changing sedimentation conditions. The basic feature of the layering is the layer – plate-like structure of the same petrographic composition with predominantly flat dimensions. Depending on the power, the layering is generally labelled (the thickness of the layer is greater than 25 cm), the slab (the thickness of the layer is 1 - 25 cm) and the laminar (the thickness of the layer is less than 1 cm). The strength of the layers may fluctuate in the area, in the case of thinning it is talked about the deflection and, in the case of the thickness of the layer; the thickness of the layer is increased. [7]

5. Reclamation in Ervěnice

The interest area of Ervěnice, which has been reclaimed since 2011, has been selected to assess the impact of the use of the secondary energy products from the Komořany heating plant for reclamation under specific conditions.

5.1. Location and geology of the area of interest

As previously mentioned, there is an area of interest situated in the North bohemian brown coal basin in the area of the Komořansko - ervěnice sedimentation, influenced by the volcanic activity of the Bohemian central mountains. It consists of tertiary basin sediments with significant deposits of brown coal. In their deep subsoil there are found tertiary springs and sediments of volcanic origin, as well as the older rocks of Krušnohory crystalline.

Morphology of terrain and quaternary sedimentation completely changed the extensive mining of brown coal, started with deep mines in the middle of the 18th century. After its termination, the interested area was extracted from the surface quarries, which for the most part obtained the remnants of the seam left over by the deep mining. Thus, not only all original quaternary sediments, but also most coal seams, including the tertiary overburden, were extracted. [4]

In that locality, the mining was first deeper (chamber) and then the surface - since 1865 Robert mine (later Šmeral) and since 1902 the Hedwyka mine, because in this area were at that time optimal conditions for the development of quarrying. [2]

After the surface mining was finished, the quarry pits were gradually laid down by depositing the overburden and subsequently filled with floated clay soil from the skirmishes of other quarries in the area. Later, after the float, some large pits were created with extensive water surfaces. Part of the quarry pits was loaded with a variety of materials, which are made up of sand, clay, and ashes, cinder and various building materials with a high proportion of coarse (rocky and boulder) fractions. These varied weights have a distinctly different character from flooded clayey soil from the overburden of surrounding quarries. After the shutdown, the site was partially used as a landfill of sand and small gravel materials.

The implementation of forest reclamation is considered in the area plan of Most, in the area in question, since it follows directly on the previously reclaimed area with subsequent afforestation, realized in the west direction, continuously with the first class road No. 13 (E442). Reclamation and afforestation of the site should contribute to the ultimate reduction of dustiness of the area used for the storage of sand and gravel materials.

5.2. Legislative framework

In order to carry out the redevelopment of the area it was necessary to assess the intention from the aspect of valid legislation. Based on the technical possibilities of the preparation of the territory and

the necessity to fulfill the legislative requirements, the locality was divided into two parts and it was decided on the phasing out of the process of implementation of sanitation and reclamation works. The eastern part of the locality with a sandy and gravel surface was dealt with in the 1st stage and the western part, including the water surface, then to the 2nd stage.

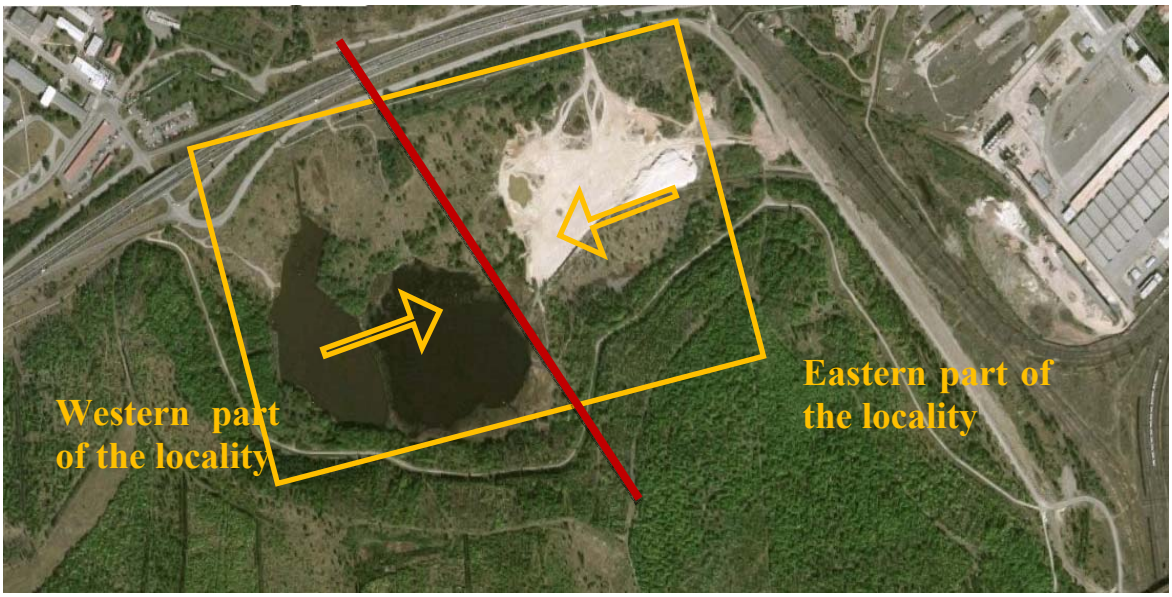


Figure 2. Separation of interested area Ervěnice [5]

The intent of the first stage would be assessed in accordance with § 6 of Act No. 100/2001 Cod., as amended, and classified according to annex No. 1 into category II, point 1.3 - Water management or other modifications affecting the runoff conditions on the area 10 to 50 ha. For this part of the site was subsequently issued a Decision on the change of use of the territory and the location of the construction and also a Building permit for the execution of a water work consisting of the construction of drainage for the purpose of extracting rainwater from the area concerned.

The basic conditions that emerged from the legislative discussion included, in particular:

- before starting works, ensure expert judgment, which excludes potential risks associated with undermining, respectively proposing measures
- construction of a drainage ditch to remove all water outside the area of interest
- during the implementation of field modifications, geotechnical monitoring will be carried out in order to check the limit values of the plastic deformation of the subsoil and the surrounding terrain
- to carry out a long-term monitoring of the impact of the deposition on the quality of groundwater and surface waters and the change in drainage conditions, in particular the assessment of the leachability and health safety of SEPs, monitoring the impact of deposition on the quality and direction of groundwater flow and surface water quality.

In this research, a comprehensive evaluation of the long-term results of the above specified monitoring will be carried out.

For the second stage, which also fulfils the conditions for classification according to annex no. 1 to Act No. 100/2001 Cod., in category II, point 1.3 - Water management or other adjustments affecting the drainage conditions in the area of 10 to 50 ha, an inquiry procedure pursuant to § 7 of the cited Act

No. 100/2001 Cod., and it was decided that the project has a significant impact on the environment and must be assessed according to the cited law.

The assessment will, among other things, be carried out:

- Geotechnical assessment for the possible occurrence of uncovered or flooded old mine workings that would need to be repaired before to the commencement of the storage of the certified construction product.
- Verification of the bearing capacity of the area, the strength of the aquifer and the depth of the solid foundation of the existing water surface.
- Designing the method of extraction and drying.
- Design of geotechnical monitoring focused on slope stability of the deposit and eventual plastic deformation of the subsoil including the design of critical indicators.
- Designing long-term monitoring of the impact of deposition on the quality of groundwater and surface water with a proposal of critical indicators.
- Assessing the possibility of influencing the recipient by water discharged.

5.3. Biotechnological land reclamation using SEPs

In general, we can say that biotechnical reclamation can be divided into two phases according to the nature of the work. The first phase is a technical one in which technical activities predominate and the second phase is biological, in which work related to the revitalization of the territory prevails.

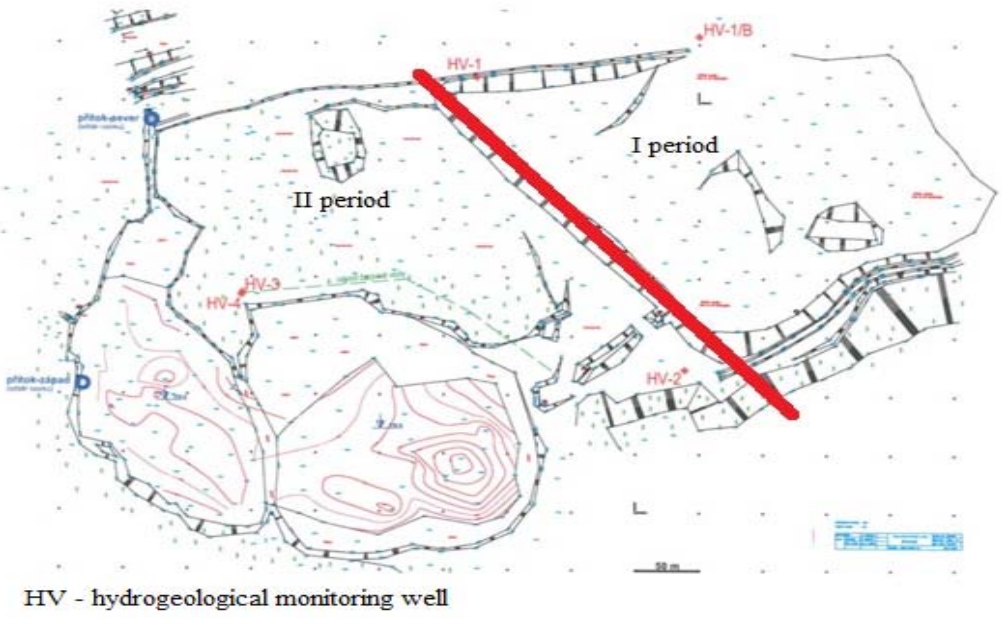


Figure 3. Situation of deploying boreholes for monitoring [8]

In the area of interest, the technical phase of reclamation with the use of previously specified secondary energy products has been proposed. This material was used for the necessary modelling of the terrain and subsequently overlaid with fertilising soils.

In the territory, in accordance with the above-mentioned territorial plan, the implementation of biological reclamation was required in a forestry manner, leaving part of the natural regeneration areas. In this case, it is a purpose forest, which fulfils in particular the function of soil protection.

The division of the locality into two periods of implementation made it possible, taking into account the results of the legislative discussion, to carry out the work within the first stage. On the basis of the relevant decisions, monitoring wells for long-term monitoring of the impact of the construction on the quality of underground and surface water, change of drainage ratios and assessment of leachability and health safety of SEPs were first built. Monitoring was started with so-called zero measurement already in the frame of the legislative discussion, based on which the background values were determined, respectively the input state in the site is determined for further assessment.

Subsequently, drainage ditches from the northern, southern and eastern sides of the area of interest were established to carry captured surface water into the water area in the western part of the land (2nd period). Prior to weighing of the SEPs material, a network of measuring points for geotechnical monitoring has been installed at the site to check the limits of the values of the plastic deformation of the subsoil and the surrounding terrain. Afterwards, the material was progressively weighed, deposited and compacted in approximately 0.5 m thick layers.

Geotechnical monitoring was carried out throughout the technical part of reclamation. Based on measurements from the course of the realization, it can be stated that the observed decrease of the bedrock was in the range of 20 - 85 mm, with the limit of the fall of the bedrock being set at 500 mm.

After reaching the total height of all the projected layers at a total height of approx. 6 m, the fertilization of the soil was carried out for the possibility of carrying out the biological phase of reclamation. Throughout the perimeter of the earth body, forest seedlings and landscape shrubs were planted in accordance with the approved biological reclamation project. Nowadays, continuous growing care is carried out at the site of the first period, with the growth and involvement of seedlings being monitored, [8, 9].

6. Impact of reclamation using SEPs on the environment

6.1. Identifications of impacts on groundwater and surface water

To determine impacts on groundwater, a hydrogeological survey was carried out, in which exploratory drilling was realized. Among other things, it was found that the southwest part of the locality is affected by the level of water in the lagoons of the western part of the territory, which is influenced mainly by the inflows of precipitation water and subsequently partly absorbed into the shallow collector kept at the southern edge of the area.

In the eastern part of the site, the local underground water flow is directed southwards to the southwest and is strongly influenced by the permeable positions of the younger settlers in the area of interest. This part of the territory manifests itself as a significantly drier area. The boreholes were well equipped and used as monitoring wells. Monitoring of groundwater quality and groundwater levels has taken place since the beginning of the technical reclamation and subsequently for a further 5 years, with the results being continuously evaluated and, among other things, provided to the state administration authorities.

From the point of view of influence on surface and underground water, the area of interest is a free-flowing area where natural rainfall flows from the area of the road no. I / 13 and leakage water flows into it. The functionality of the drainage system of the former reclamation in the western area of the site was not investigated, taking into account the noted observations during about 6 months, when no flow in the drainage system was detected. Outflowing water from offshore depression is only possible through layers of varied permeable bundles, which form, in particular, the upper (shallow) horizon of the inner dump of the quarry, [4,10]

For the purpose of groundwater monitoring in a given location, four wells were performed. In heterogeneous environments consisting of alternation of permeable positions and clayey layers, monitoring objects are susceptible to fouling with fine sludge. The sludge at the bottom of the borehole was found in the powers of 9 to 19 cm in 2017. The currently low slurry power did not affect the well function. (see Table 1)

Table 1. Borehole depth overview

MONITORING OBJECT	HV-1	HV-2	HV-3	HV-5
Depth of borehole after installation (m under ter.)	12.0	12.0	11.5	9.5
Depth of borehole of 26.9.2012 (m u.t.)	11.95	11.8	11.0	8.6
Depth of borehole of 16.4.2013 (m u. t.)	11.85	11.3	11.2	9.37
Depth of borehole of 25.9.2013 (m u. t.)	11.85	**11.7**	11.2	9.37
Depth of borehole of 15.5.2014 (m u. t.)	**11.95**	11.7	11.2	9.07
Depth of borehole of 26.9.2014 (m u. t.)	11.85	**11.8**	11.2	9.07
Depth of borehole of 16.4.2015 (m u. t.)	11.85	11.8	11.2	9.07
Depth of borehole of 29.9.2015 (m u. t.)	11.85	11.8	**11.4**	**9.47**
Depth of borehole of 29.4.2016 (m u. t.)	11.95	11.73	11.36	9.4
Depth of borehole of 29.9.2016 (m u. t.)	12.0	11.81	11.36	9.5
Depth of borehole of 27.4.2017 (m u. t.)	12.0	11.86	11.41	9.5
Depth of borehole of 22.9.2017 (m u. t.)	12.0	11.81	11.41	9.5

Note: boldly highlighting depths after de-sludge

The groundwater level was encountered only in two wells at a depth of about 6.5 m and in one well the water level was not encountered at all. The groundwater level is shown in Figure 4 and the Table 2. A drainage ditch will be built around the eastern part of the territory to ensure the drainage of surface water, which will be used in case of rainfall precipitation, especially during the course of technical reclamation.



Figure 4. Progression of groundwater level in monitoring wells [7]

Table 2. Overview of stable groundwater levels

DATE	**OBJECT**	**HV-1**	**HV-2**	**HV-3**	**HV-5**
4. 4. 2012	GWL (m under ter.)	6.26	7.25	2.6	-
	Z-GWL (m a. s. l.)	223.55	221.83	226.56	-
31. 7. 2012	GWL (m under ter.)	5.27	9.12	2.72	2.04
	Z-GWL (m a. s. l.)	224.54	219.96	226.44	229.51
26. 9. 2012	GWL (m from MP)	5.49	10.47	3.41	2.53
	Z-GWL (m a. s. l.)	225.17	219.3	223.34	229.65
16. 4. 2013	GWL (m from MP)	5.35	4.55	3.1	2.02
	Z-GWL (m a. s. l.)	225.31	225.22	226.65	230.16
25. 9. 2013	GWL (m from MP)	5.67	9.11	3.17	2.44
	Z-GWL (m a. s. l.)	224.99	220.66	226.58	229.74
15. 5. 2014	GWL (m from MP)	5.58	10.3	3.21	2.55
	Z-GWL (m a. s. l.)	225.08	219.47	226.59	229.63
26. 9. 2014	GWL (m from MP)	5.12	4.15	3.16	2.01
	Z-GWL (m a. s. l.)	225.54	225.62	226.59	230.17
16. 4. 2015	GWL (m from MP)	5.65	2.18	2.98	2.08
	Z-GWL (m a. s. l.)	225.01	226.96	226.77	230.1
29.9.2015	GWL (m from MP)	7.23	9.45	3.52	3.02
	Z-GWL (m a. s. l.)	223.43	220.32	226.23	229.16
29.4.2016	GWL (m from MP)	6.67	8.38	3.19	2.24
	Z-GWL (m a. s. l.)	223.99	221.39	226.56	229.94
29.9.2016	GWL (m from MP)	8.62	10.07	3.64	3.2
	Z-GWL (m a. s. l.)	222.04	219.7	226.11	228.98
27.4.2017	GWL (m from MP)	8.5	7.88	3.62	2.12
	Z-GWL (m a. s. l.)	222.16	221.89	226.13	230.06
29.9.2016	GWL (m from MP)	10.21	10.04	3.91	3.05
	Z-GWL (m a. s. l.)	220.45	219.73	225.84	229.13

Note: GWL …… groundwater level - relative value
(m under ter) …….. m under the terrain
(m from MP) ..... m from the measuring point (upper edge of the bore of the borehole)
Z-GWL ..... groundwater level - absolute value, relative to meters above sea level

The quality of the groundwater in the locality is determined mainly by the character of the original strains prior to the start of the work on the technical reclamation, which is also confirmed by the results of the realized monitoring. Therefore, the quality of underground water that flows from the slopes of the surrounding internal dump is observed.

Surface water is qualitatively monitored only in the lagoons because no accumulation of precipitation water has been detected in the northern and southern ditch, and the western part of the northern trench cannot be considered representative because its inflow is also formed by the water discharged from the surface of the nearby road no. I/13.

6.2. Impact on air and noise at the locality

The area is overloaded with noise. In the area of interest there are a number of sources, namely the municipal noise, mainly caused by traffic (railway line ČD, road No. I / 13), as well as the noise generated by industrial sources, namely the Komořany coal processing plant and Komořany heating. A remarkable source is also a nearby autodrome. Industrial sources in normal operation are steady or slightly variable noise. However, the noise situation is mainly influenced by the time-varying communal noise from road traffic and autodrome. In some places and at a particular time of day, the situation can be quite unfavourable. At present, however, there is no assumption of a change in the noise situation in the locality being solved, [2].

Air and noise will therefore be more affected in the area of interest only during the period of technical reclamation. These facts have been assessed in accordance with the valid legislation in the framework of environmental impact assessment pursuant to Act No. 100/2001 Coll. Significant negative influence on air quality and noise in the area of interest was not proved in the framework of the investigations and assessments carried out, taking into account the current use of the site, as described above, in an industrial area whose influence is dominant. Based on these facts, monitoring of these impacts was not performed in the site.

In order to minimize the increase in dustiness at the time when the building mechanization and movement of the means of transport will be carried out in the locality during the CBPs weighing, it was ensured that it was spattered, especially during the dry months of the year.

7. Conclusion

The use of secondary energy products produced by fluidized combustion, especially in first period, proved to be very appropriate, given the fact that the relatively close source of the certified granulate is. Subsequent monitoring has not yet shown negative impacts of groundwater and surface water and due to the relatively short period of implementation of technical reclamation there has subsequently been a reduction of dust in the given locality and overall improvement of the state of the area concerned. Possibility of modification of the western part of the site within second period with the use of the additive granulate will be further investigated, both in terms of technical feasibility, environmental impact and economic demands, which are influenced by the extensive modelling of the terrain in this part of the site.

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