Geotechnik im Bauwesen
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Short report

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Research topic: Geothermal Utilization of Smouldering Mining Dumps

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Project Description and Results

Mining dumps are a well known appearance in coal-mining areas. Less known is the fact, that in many of these dumps smouldering fires are a common phenomenon. The smouldering originates from an oxidation of residual coal with atmospheric oxygen. Due to a bad compaction of the material oxygen transfer is possible, which-in combination with heat accumulation- can lead to a combustion process within the dump. The resulting high temperatures represent a high energy potential, which has not received much attention yet. In a co-operation of the Chair of Geotechnical Engineering, the Unit of Technology of Fuels, the DMT GmbH & Co. KG, Expert Body for Fire Protection, the Fraunhofer Research Institute UMSICHT as well as the consulting firm aix-o-therm GeoEnergien the geothermal utilization of smouldering mining dumps has been investigated over five years (2008 - 2013) using the example of a mining dump in the “Ruhr Area”.

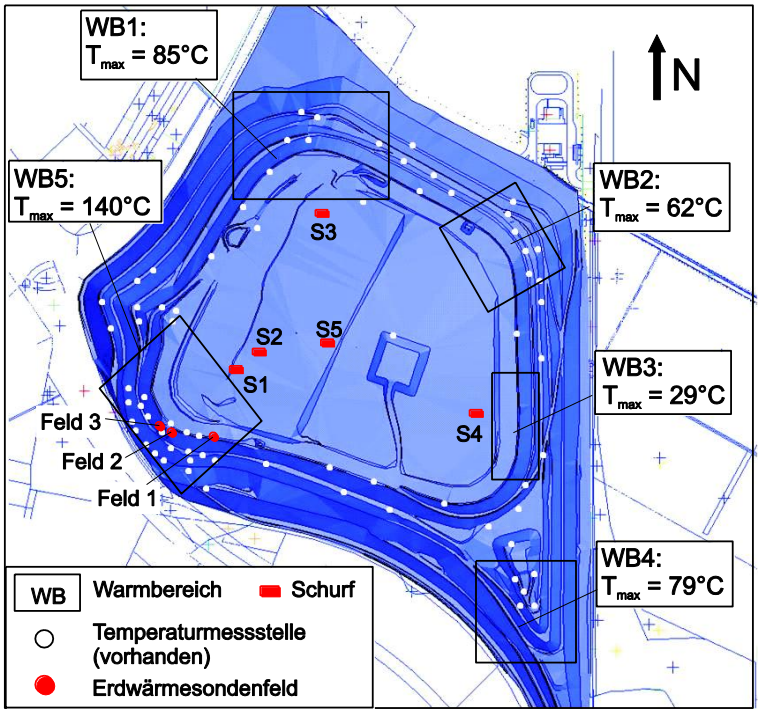

Figure 1: Dump Site (Position of Hot Spots (WB), Borehole Heat Exchangers and Test Pits)

For this purpose three coaxial borehole heat exchangers (BHE) with a length of 25m each were installed in one of the hot spots at the edge of the dump plateau (see Figure 1 and Figure 2). For reasons of control and data acquisition of the temperature profile inside the dump body five measuring gauges were arranged in a semi-circle around each BHE. Additionally, five test pits with a maximum depth of 9m were excavated to extract material samples.

Figure 2: Drilling work

The encountered temperatures in the underground varied between 70°C and 430°C (see Figure 3) and were much higher than expected. The temperature maxima were encountered at a depth of about 15m. The temperature profiles were measured several times, so that the response of the dump material to the heat extraction could be controlled.

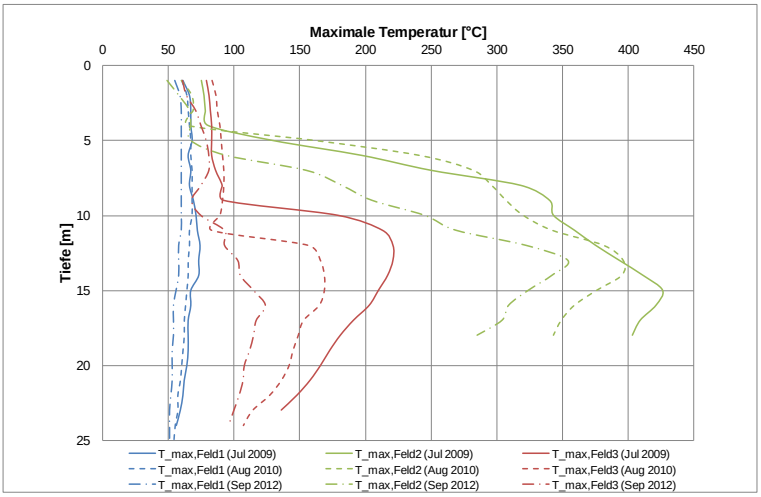

Figure 3: Temperature in the ground

Several Thermal Response Tests (TRTs) were conducted to investigate the short-term efficiency of the geothermal probes. For determining the optimum operating condition, the tests were carried out at different heat capacities. For BHE 2 and BHE 3 a constant heat extraction of 3kW and for BHE1 of 1kW was possible to achieve a steady operation state. The resulting effective thermal conductivity varied between 1.0W/mK (BHE 3) and 2.1W/mK (BHE 2).

The long time-behaviour of the BHEs was investigated with the help of long-term heat extraction tests. For this purpose, the pilot plant was operated at a total heat extraction of about 8kW over one year, approximately. With the exception of BHE 3 a steady operation state could be achieved. This is proved by the less reduction in temperatures in field 1 and 2 over time (see Figure 3). Hence, a long-term operation of borehole heat exchangers on a smouldering mining should be possible. The extracted energy could be used for heating the company buildings of the dump owner, for example. In heat exchanging field 3 a significant drop in temperatures was measured (see Figure 3). Additionally, a decrease in the heat extraction rate was observed. It remained unclear whether the temperature drop results from the heat extraction or from the natural

development of the smouldering fire. Therefor, additional research on the time depending behaviour of a smouldering inside a dump is necessary.

The heat extraction rates, which were realized in the field tests, showed at about 100W/m much higher values than common near surface geothermal systems (50W/m on average). Nevertheless, with respect to the high temperatures (up to 400°C) the heat extraction rates were not as high as expected. To identify possible reasons, several practical and theoretical analyses were carried out. Therefor, the thermal conductivity of the dump material was measured with the help of laboratory tests. The measured values varied between 0.4W/mK (dry conditions) and 1.3W/mK (saturated conditions). It becomes clear, that the low thermal conductivity of the dump material is one of the limiting factors for the thermal utilization of a smouldering mining dump. It can only to some degree be compensated by the high temperatures within the dump. This effect is enhanced by the limited heat generation inside the dump.

For safety reasons all boreholes were backfilled with dry sand. For an optimization of the plant the use of thermally improved and heat-resistant backfill materials were investigated. Therefor, the thermal conductivity of alternative backfill materials was measured in the laboratory as well. The influence of the backfill material on the heat output was investigated by numerical simulations. It could be shown, that the efficiency of the system can be increased significantly by the use of homogenized, thermally improved materials (e.g. heat-resistant cement-based materials).

The decisive parameters on the heat output of the pilot plant were determined by numerical simulations as well as parameter studies based on analytical models. The investigations have shown, that apart from the site conditions (thermal conductivity of the dump material and temperatures inside the dump) the operating conditions of the plant (flow conditions inside the heat exchanging system) as well as the geometry of the BHEs (optimal ratio of inner and outer pipe diameter) have a significant influence on the heat output of a geothermal probe located on a smouldering mining dump.

Further information about the project can be found in the project reports and in the following publications:

Kürten, S., Feinendegen, M., Noel, Y., Gaschnitz, R., Schwerdt, P., Klein, A.: *Geothermal Utilization of Smouldering Mining Dumps as a Substitute for Fossil Fuels.* In: Latest Developments in Coal Fire Research Bridging the Science, Economics, and Politics of a Global Disaster Proceedings of "ICCFR2 I Second International Conference on Coal Fire Research" 19-21 May 2010, dbb forum Berlin, Germany / Compilation: Richard A. Eichler, Freiberg 2010, ISBN: 978-3-86012-397-3

Kürten, S.: *Geothermische Nutzung von Haldenschwelbränden*. In: 31. Baugrundtagung - Forum für junge Geotechnik-Ingenieure: Beiträge der Spezialsitzung; 3-6 November 2010 in München / Hrsg.: Deutsche Gesellschaft für Geotechnik e.V. , Hildesheim, Wecom, Ges. für Kommunikation, 2010, S. 167-174, ISBN 978-3-9813953-3-4.

Kürten, S., Feinendegen, M., Schwerdt, P., Noel, Y., Klein, A., Gaschnitz, R.: *Haldengeothermie - Chancen und Risiken bei der thermischen Nutzung von Haldenschwelbränden.* In: Geotechnik 34 (2011), H. 2, S. 127-135, ISSN 1865-7362.

Kürten, S., Feinendegen, M., Ziegler, M., Noël, Y., Quicker, P.: *Haldengeothermie – Besonderheiten bei der thermischen Nutzung von Haldenschwelbränden*. In: Der Geothermiekongress 2011 : Bochum 15. - 17.November 2011 ; Kongressband / Hrsg.: GtV-Bundesverband Geothermie e.V., Berlin 2011, S. 1-12, ISBN 978-3-932570-66-7

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Kürten, S.; Feinendegen, M.; Noël, Y.; Gaschnitz, R.; Klein, A.; Schwerdt, P.: *Thermische Nutzung von Haldenschwelbränden – Erkenntnisse und Erfahrungen aus einem Pilotprojekt.* In: Mining Report 149 (2013), H. 2, S. 116-124, ISSN 2195-6529.

Kürten, S.; Feinendegen, M.; Noël, Y: *Geothermal Utilization of Smoldering Mining Dumps*. In: Stracher, G.B., Prakash, A.; Sokol, E.V. (Ed): *Coal and Peat Fires: A Global Perspective – Volume 3: Coal Fires – Case Studies*. In Press.