Van: @akzonobel.com>
Verzonden: woensdag 11 juli 2018 10:15
Aan:

Onderwerp: 26 July 2018 work session on seismicity - brief progress overview

Dear seismic team (plus SodM "observers"),

On 19 November 2017 an unusual seismic signal was observed which was later (mid December 2017) determined as an event that occurred in the Heiligerlee cavern field. This initial location was determined to be close to HL-K at a depth corresponding to the depth of the cavern. KNMI indicated a large uncertainty (>500m) in all directions based on the 2D velocity model used. The location of the event was not precise enough to indicate a specific cavern and a precise depth because (1) determining arrival times was ambiguous and (2) a 3D velocity model was not included in the analysis.

This email serves to give a brief progress overview of all the work done so far and to be a basis for our face-to-face work session on 26 July 2018 in Hengelo. It contains some (intermediate/preliminary) conclusions that require further discussion and validation.

KNMI work

A revised report by KNMI dated 5 March 2018 identified four events in a time lapse of 60 seconds. The preliminary epicentre of the main event was situated on top of the Heiligerlee salt dome at a depth of maximum 1.5 km. The location was based on manual picking of P and S-wave arrivals and a 2D velocity model.

KNMI indicated that they will acquire the local 3D velocity model and use it to locate the Winschoten events with greater accuracy. KNMI will determine the magnitude and/or seismic energy of the 19 November 2017 Winschoten events. KNMI will perform a moment tensor inversion of the events (at least the largest one) to assess whether the moment tensor contains a large isotropic component. AkzoNobel, Magnitude and Arup will discuss this (and other items) with KNMI on 25 July 2018.

KNMI also reviewed Arup's design of the dedicated seismic monitoring system in Heiligerlee to supplement its own network. Magnitude (a Baker Hughes company) will install and operate this network before end of Q3 2018. KNMI indicated to keep a closer watch on the Heiligerlee cavern field until the local seismic network is in place. These topics will also be discussed with KNMI on 25 July 2018.

Literature survey

Arup studied the literature on seismic events connected to salt caverns and salt domes globally. There are generally two types of seismic events: micro-earthquakes and blocks falling. They differ in terms of frequency content and source focal mechanism. Seismic hazard can be anticipated through analysis of the magnitude-frequency distribution of seismicity. From this survey it was concluded that a local seismic network should be able to detect and locate events with a magnitude down to -1.

Notably the Napoleonville Salt Dome, located near Bayou Corne, southeast Louisiana shows similarities and differences to our Heiligerlee and Zuidwending fields. Similarities are that HL-H is of comparable size and also located at the edge of the dome at approximately the same depths. Differences are that the safety distance to the edge is not compromised in HL-H (GPR to confirm this more accurately) and the shape of the dome does not show the same mushroom shape. Therefore this represents the top event in the bow tie risk analysis whereby the probability of occurrence is related to the geometry and physical characteristics of the cavern in relation to the dome and the effect should the event occur is related to the situation at ground surface (housing, infrastructure, etc.)

Sonar

Measurements were executed by Socon on behalf of Gasunie (HL-K) and AkzoNobel (HL-H). HL-K was the cavern initially indicated in the centre of the KNMI 500x500 m^2 area. HL-H was tested because of its relative proximity to the dome edge. The sonar measurement at HL-K did not reveal any anomalies. Initial (field) review of the raw data of the sonar in HL-H did not reveal anomalies either but a closer look showed an anomaly at a depth of approx. 1057-1077 m. This anomaly was later estimated to be a volume of salt of approx. 1,200 m^3 that had probably broken off in in several differently sized blocks.

GPR

Measurements were executed in HL-H to determine the distance to the edge of the dome. The results are expected before 20 July 2018 and can be discussed during the work session of 26 July 2018.

Falling rock

DEEP.KBB assessed / calculated which magnitudes can be caused by rock fall in the caverns. The assessment was checked by Arup to account for the different ways to assess magnitudes from energy release and to ascertain that we are consistent throughout.

In the recent months, in Hengelo, a piece of pipe fell into a cavern. The impact was recorded by the micro-seismic monitoring network and K-UTEC back-calculated the magnitude. Arup is currently checking this calculation for consistency and it can then be used to further validate the DEEP.KBB assessment.

These different assessments will be an important topic to discuss on 26 July 2018 because it connects to the possible rock fall in HL-H and forms the basis for further interpretation of (micro)events and conclusions towards possible cause of the 19 Nov 2017 events as well as the risk assessment (bow tie analysis).

Seismic network

A seismic network was designed by Arup and after KNMI review, competitively tendered whereby "salt experience" and experience in The Netherlands (Groningen) context were prerequisites to be shortlisted to tender. Magnitude was selected as successful bidder. The network comprises geophone strings in 60 m deep boreholes at four locations (close to HL-B, G, K and H) and a hydrophone string in HL-H. The monitoring system is designed to be able to detect and locate all events down to at least a magnitude of -1.0 within an area extending 500 m away from the salt caverns. The location accuracy (95% confidence intervals) is expected to be better than 50 m horizontally and 150 m vertically, in order to be to distinguish which salt cavern any measured event has occurred in or next to.

Risk assessment / bow tie analysis

We are assessing (micro) seismicity / micro tremors as a result of natural or anthropogenic processes (salt extraction) or a combination thereof. Statistics on the recorded seismicity rate (for (micro) seismic events) also provide valuable information. The rate of events tends to sharply increase and sustain an unusually high rate before a catastrophic event, such as a major collapse or the formation of a sinkhole. In combination with other measurements (e.g. sonar, GPR) more insight can be obtained about the exact cause of any (risk of) instability at Heiligerlee and Zuidwending.

The question is therefore if cavern instability can cause (micro) seismic events and if we can interpret these events to assess overall risks and the question is not if an earthquake can cause damage to a cavern resulting in instability.

The draft bow tie will be discussed further on 26 July 2018. Currently the top 1 event is a sinkhole. To compare, the sinkhole in Louisiana measured a radius of 230 m and covered an area of 16 ha. The top 2 event is soil subsidence greater than would be expected according to the extraction plan (permit). The difference with top event 1 is that top event 2 caused "milder" subsidence (less sudden). Barriers to avoid top event include measurements (incl. seismicity, sonar, GPR), validation design, incl. soil subsidence, 3D geological modelling on the basis of studies and ongoing measurements. Barriers to reduce the effects include ongoing measurements, physical barriers and acquiring affected zones/houses and evacuation.

Met vriendelijke groet,

Manager
Mining Development & Compliance
Specialty Chemicals

T: +31 6
E: @akzonobel.com

Akzo Nobel Chemicals B.V.
Boortorenweg 27
7554 RS Hengelo
P.O. Box 25
7550 GC Hengelo
The Netherlands

www.akzonobel.com/specialtychemicals