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Scientists calculate risks of further earthquakes from gas drilling in Groningen, the Netherlands

A recent overview and analysis shows that increasing amounts of gas drilling at Groningen, the largest gas field in Europe, led to a dramatic rise in regional earthquakes between 2001 and 2013. After a reduction in extraction was introduced by the Dutch Government, earthquake numbers started to fall. Statistical analysis reveals that if high extraction rates were resumed, about 35 earthquakes, with a magnitude (M) of over 1.5 on the Richter scale, might occur annually from the year 2021 onwards, including four with a damaging magnitude of over 2.5.

Even if extraction was limited to the 2017 rate set by the government (21.6 billion cubic metres - bcm), the annual number of earthquakes would gradually increase again, with an expected all-time maximum M of 4.5, a serious event capable of shaking walls and chimneys, creating considerable damage and posing safety risks to the public.

Since its discovery in 1959, the Groningen gas field has revolutionised energy use in the Netherlands, curing the country of its dependence on coal and oil. The cleaner, low-calorific Groningen gas now accounts for 40% of Dutch energy consumption and, including exports, 55 years of extraction has brought in more than €280 billion. However, this has come at a cost, with rising earthquakes in the region increasingly damaging property structures and values, posing safety risks and worrying the 300 000 local population.

The 35 km x 25 km gas field, located in the north-eastern part of the Netherlands, originally contained up to 2.8 trillion cubic meters of gas. As of 2001 about 60% of the reserves had been extracted, and, at the end of 2016, less than 700 bcm (25%) remained. Following a National Energy Outlook in 2017, annual volumes are expected to drop below 10 bcm around 2030, with the Groningen field in principle operable until about 2060.

Historically, the flat Groningen region has had little seismic activity, and induced earthquakes were, until 1986, unheard of. However, in 1991, when more than 1 200 bcm, or 45% of the total gas reserves had already been extracted, moderate earthquakes began to occur. After the year 2000 these increased in frequency and severity, until the summer of 2012 when a record earthquake, measuring 3.6 on the Richter scale, occurred near the village of Huizinge. In response, as of early 2014 the government started to lower the annual volume of gas that could be extracted. Since then, the rate of extraction has gradually fallen from 54, in 2013, to 21.6 bcm/year in 2017/2018.

Concerns about the environmental safety of underground oil or gas extraction, and its effects on seismic activity are not new. Since the 1950s, tremors have been experienced near the Caviaga gas resource in the Italian Po Valley, in the Gazli gas field in Uzbekistan, and in the North American regions of Alberta, California, Oklahoma, and Texas. Until recently, however, the advanced methodology needed to predict the effect of gas extraction on earthquakes has been absent.

The present overview and analysis is focussed on the effect that gas extraction at Groningen has had on the number and severity of earthquakes from 1990 to 2016. The researcher compared basic data on the number and size of induced earthquakes, collected by the Royal Netherlands Meteorological Institute, KNMI with annual gas-production figures, available from the Dutch oil and gas company, *Nederlandse Aardolie Maatschappij (NAM)*. Statistical trend analysis was then used to assess how the two are correlated.

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It appears that although gas extraction rose strongly throughout the 1970s, it wasn't until the early 1990s, after 45% of reservoir depletion, that the number of earthquakes around the site began to increase. After an initial slow rise, seismic activity stayed at a moderate level until 2001, despite a temporary lowering of gas extraction. However, after 2001, by which time about 1 600 bcm, or 60%, of the reservoir had been depleted, the number and intensity of earthquakes began to steadily rise in parallel with annual gas-extraction rates, up to 30 earthquakes with M ≥ 1.5 and five with M ≥ 2.5 in 2013.

The study concludes that the earthquakes are a direct consequence of the reservoir running empty on gas, rather than a result of annual extraction rates per se. As more and more gas is removed from the reservoir, the underground pressure reduces, causing the porous sandstone layer that makes up the reservoir to compact and surface soil to subside. The compaction increases the stress around many existing fault-lines, making sudden underground movements and earthquakes more likely to occur. This explains why, despite large amounts of annual gas extraction in the 1970s, earthquakes did not occur until 1991. Now that the reservoir has been largely depleted, the well-compacted sandstone layer has become highly sensitive to further extraction.

Based on extrapolation of 27-year statistical trends, it appears that if current extraction rates of about 20 bcm/year continue, by 2021 about 13 earthquakes with an M ≥ 1.5 will occur per 20 bcm of extraction. In the 2040s, if extraction continues, the study projects that there will be about 19 earthquakes per 20 bcm (nine to ten earthquakes per 10 bcm).

The earthquakes would also become increasingly severe. In the next 10 to 17 years, if extraction continues at any rate, the maximum expected earthquake magnitude will be about 4.0, and an earthquake measuring 4.5 might occur within the next 30–50 years. An earthquake with an M of 5.0 is unlikely to occur, but this possibility cannot be ruled out.

The analysis suggests that, either increasing annual extraction or maintaining a stable rate of extraction would lead to further earthquakes, and reduced seismic activity could only be achieved by a steady year-by-year reduction in annual gas extraction.

However the researchers also note that there is lack of expert agreement among the gas field's operator, the Dutch Petroleum Company, NAM, the state supervisor of mines, *Staatstoezicht Op De Mijnen* (SodM), and the advisory Mine Council about the validity of different models for risk calculations, safe levels of gas extraction and the effects of further reservoir compaction.

Nevertheless, to reduce the risks posed by extraction of the Groningen gas field, various strategies are suggested, such as decreasing gas extraction for an extended period, reinforcing houses and community buildings, offering protection and emergency assistance to potential victims, and compensating people for actual earthquake damage and having to live with safety risks. The majority of these strategies can be recognised in recently developed government policy[1].

However, in the study, it is argued that more attention could be paid to the widespread anxiety, stress and resulting health effects that locals living above the Groningen field are experiencing. Policies that address these fears would go some way to restoring people's confidence in their own environmental safety and restore their trust in experts and policymakers.

1. Throughout 2017 seismic activity did not further diminish, with a total of eighteen earthquakes with M ≥ 1.5. Between January and-April 2018, nine such events have occurred. In January 2018, just after this study was published, Groningen was hit by an earthquake measuring 3.4 on the Richter scale, with an unusually high peak ground acceleration, the biggest in the region since 2012 and the third strongest ever recorded. As a result, the Dutch government went through a rapid sequence of judgements and decisions, with the result that annual gas extraction is to be lowered to at most 12 bcm/year as soon as possible before 2023, and that the Groningen field will cease to operate around the year 2030, when the huge reservoir would still contain some 400 bcm of natural gas. Two immediate strategies to reduce the demand for Groningen gas are to oblige some 200 energy-intensive companies to stop sourcing gas from the Groningen field before 2023, and to diminish traditional gas exports to Germany, Belgium and France.

As of May 2018, it is unclear what seismic activity may be further expected and, thus, which risk-mitigation measures will be required, The decision to fully end Groningen gas extraction within 12 years, however, will likely reduce a recently developed, large-scale operation aimed at reinforcing or rebuilding thousands of vulnerable houses and other structures. Meanwhile, some experts are campaigning for the continuation of gas extraction while preventing further reservoir compaction via the injection of nitrogen.