Fracking wastewater

Water use

Hydraulic fracturing (or fracking) makes use of large quantities of water into which chemicals and proppant (mainly sand) is mixed. The process starts by drilling a vertical well which, when it reaches the shale deposits it is turned horizontally. A "necklace" of shaped explosive charges is inserted, which when detonated produce a series of holes in the pipe. The fracking water is pumped at a high pressure (depending on the depth), which forced from the holes, produces "fractures" in the shale, which are then "propped" open by the proppant, mainly sand, to prevent the fractures from closing and to let the oil or gas in the shale to be released once the hydraulic pressure is released.

Once the hydraulic pressure is released, some, but not all, of the injected water flows back to the surface as "flowback", which contains some of the recovered oil or gas from the shale and which is then separated from it, though not totally. The initial flowback ends and is then followed by the "produced" water which arises with the product.

The amount of new water used for fracking varies from 8,000 to 23,000 cubic metres per well (2 million to 6 million US gallons). Some of the produced water can be treated on the well pad and re-used.

Wastewater composition

A mixture of the returned flowback and produced water contains some of the added chemicals and proppant, but also dissolved toxic metal salts, some radioactive, from the shales into which the initial water was injected. There is also a certain amount of dissolved methane and other petroleum compounds in it, including volatile organic compounds (VOCs). The biggest problem is the raised salinity expressed in total dissolved solids (TDS), which can be many times more than that of seawater. If treated for re-use, the residual wastewater from the treatment process will have its salinity even more raised, while the concentration of the toxic dissolved solids and the radioactivity will be increased.

Wastewater handling by the wells

In the US wastewater is stored adjacent to the drilling pad in lined open pits (impoundments, or lagoons) prior to disposal. This is highly problematic as the dissolved gas and petroleum compounds evaporate and cause health problems. Liners can leak and rain downpours would lead to overflow and local ground contamination. Some sites have more than one impoundment, which can be the size of a football pitch. Some impoundments have caught fire with lightning strikes, because of the petroleum content.

Open pits are prohibited in the UK and double-skinned tanks are deployed for the on-site storage of the wastewater. There will have to be multiple tanks to cover the initial chemicals and sand addition, to hold treated wastewater for re-use, to hold concentrate from the re-use treatment plant for disposal and to contain the flowback and produced water. As the returned water will displace the atmosphere in the enclosed tanks the tops will be connected to a flare stack to burn off the dissolved methane and other petroleum compounds.

In the US the evaporation of the volatile organic compounds from the open pits has led to the huge health problems of neighbouring people and animals, covered up by leasing and royalty "gagging" agreements. VOCs can be benzene, ethylbenzene, toluene, xylenes, *n*-hexane, carbonyl sulphide, ethylene glycol and/or 2.2.4-trimethylpentane.

There are two main means of wastewater disposal, deep well injection of it untreated and by transfer to a treatment works.

Deep well injection

In the US the wastewater is trucked to regulated deep injection wells, which are tested and classified for specific uses. Fracking fluids are handled in Class II wells. Although there are thousands in use they are insufficient to handle the vast amounts of wastewater arising from fracking operations. There was a major explosion at an injection well at

Denver when lightning ignited the dissolved gas and petroleum in a delivery of wastewater.

The practice is prohibited in the UK and there is not the regulatory infrastructure established as in the US. If subsequently allowed, there would have to be seismic exploration and drilling to find suitable deep porous rocks able to store the fluids securely. There has been some re-injection in redundant conventional wells, but the number of these would be insufficient for the intensive fracking intended. Re-injection into shales is not practical as they are not porous enough.

Oklahoma has recently become the most earthquake-prone state in the US which scientists say are due to the re-injection of wastewater as part of the fracking process. Oklahoma suffered 138 earthquakes of magnitude 1.5 or greater in the October 2016 alone, adding up to 2,199 over the past year — including its largest quake ever, one of 5.8 magnitude in September 2016. In Ohio in March 2014 there were dozens of earthquakes, including one of a magnitude of 3.0.

Quantity of wastewater to be treated

The question is how much wastewater will be treated if fracking is established to provide a substantial amount of the UK's natural gas consumption? Until a field operationally matures, the recovery factor and ultimate well recovery will not be known.

Natural gas consumption in the UK in 2014 was 2,400 bcf, so that 15% of this is 360 bcf a year. With an ultimate estimated recovery of 1.3 bcf/well it requires, once steady state production is achieved, 300 wells to be drilled a year. The final amount of flowback and produced water together can be 20,000 cubic metres per well. The quantity of fracking wastewater for treatment is then 20,000 x 300 = 6 million cubic metres a year.

Treatment plants

The initial test drilling by Cuadrilla in Lancashire resulted in 8,000 cubic metres being trucked to United Utilities Davyhulme works on the side of the Manchester Ship Canal in 300 road tanker movements. What happened to it is not revealed, but the works has since declined to request a permit for further inputs.

In the treatment works, the suspended solids, together with some precipitated dissolved solids as sludge are settled in sand or filtered and the sand and filter cake together with the filter aids are sent to landfill. If the sludge is radioactive it has to be sent to a specialist low level radioactive repository.

However, as the toxic salts and NORM in the flowback and produced water when treated will scale up the pipework and equipment, the treatment plant may have to install a dedicated plant line for fracking wastewater with cleaning-in-place (CIP) to maintain its flow. The methane and VOCs dissolved in the wastewater may also be problematic.

However, the high salinity of the treated water means it cannot be disposed of into an estuary, whereby the upper waters are less saline than the sea or even into the sea, unless it can be diluted with perhaps five times its volume with other less saline effluent streams.

Municipal sewage works are unable to take in fracking wastewater. A Hansard entry for 17 July 2016 nominated three treatment plants with permits, viz., Castle Environmental at Stoke-on-Trent, FCC Environment at Leeds and Bran Sands at Middlesbrough. The Stoke-on-Trent and Leeds plants discharge into the Trent and Aire rivers and are therefore unlikely to be able to dispose of the high fracking wastewater salinity.

Bran Sands waste treatment plant

The Northumberland Water Bran Sands treatment works at Middlesbrough is equipped with sewage sludge handling and anaerobic digestion and has an industrial treatment section capable of 200,000 cubic metres per day which may be augmented with additional facilities for treating fracking wastewater. It is by the Tees mouth and could, with a pipeline, discharge far out to sea, but the toxic salts and radioactivity would have to be removed beforehand.

Bran Sands has a "Consent to Discharge" for its sewage effluent, but as there is a separate consent for its industrial side, the conditions for discharge need to be checked against the potential analysis of the treated fracking wastewater.

The Bran Sands plant is currently the most likely treatment works in the UK able to take in fracking wastewater in sufficient quantities, but is 130 miles from the test drillings in Lancashire. The 20,000 cubic metres of wastewater per well would require 900 or so road tanker journeys to it. Bran Sands has a permit for disposal of radioactivity from its treatment of wastewater from off-shore oil and gas rigs landed by ships.

Cuadrilla enquired as to Bran Sands ability to take in its wastewater, but has not so far submitted the requested sample. Shale gas operators have to demonstrate to EA that they have a written agreement from a company with a radioactive substances activity permit that can treat and dispose of their waste for the EA permit application process to be validated. No such agreement has been signed between Cuadrilla and Northumbrian Water and the operations in Lancashire cannot be initiated.

Permits

The flowback and produced water must be analysed before the issuing of an EA permit for disposal. The selected ultimate disposal method, deep injection well (if there ever is one) or treatment works needs a permit for acceptance of it. It also needs permits for the disposal of the treated water, for the sludge and filter aids to landfill, the transport of the radioactive sludge and for the acceptance by the low level radioactive repository. As until fracking flowback and produced water arise at the surface it cannot be analysed, the analysis of the Preese Hall wastewater is available and gives an indication of the likely analysis of the water from the four new test drillings.

Processing of high TDS wastewater

The limit for treatment of high TDS by reverse osmosis (RO) is 50,000 mg/l. The osmotic pressure to be reversed rises with the TDS, making the construction of the membrane modules impractical. As Cuadrilla's wastewater has a mean TDS of 170,000 mg/l (with for NaCl an osmotic pressure of 156 bar) RO will not be an appropriate method of reduction of its TDS before disposal. The only possible practical method is Mechanical Vapour Compression (MVC) and which is used in a containerised version on site for wastewater re-use. The compressor, driven by a diesel engine, provides the evaporation heat.

Even so there will be two halves for disposal, the cleaned up half for the estuary or a large water course, but the concentrated half may have to be subject to further evaporation for crystallisation, because its TDS would be double that in the original wastewater.

Energy inputs

The whole process of fracking and the handling of the wastewater is energy intensive, particularly the use of the chain of coupled high pressure pumps for the hydraulic injection of the fluid into the shale. (Up to 100 MPa; 15,000 psi). The regulated wastewater handling adds further energy intensity to the entire process with the energy requirements for the MVC (or RO) and its road tanker transport.

Veolia has developed a vacuum evaporation process for dealing with the high salinity and it has been asked to state the energy requirement per cubic metre of wastewater treated.

There are additional energy costs for the provision and management of the double-skinned tanks over those of the open pits common in the US and considerable energy losses in the initial flaring of the product until it can be piped away.

If injection wells are eventually conceded then the transport to them and the high pressure pumping needed for the injection will incur energy inputs.

It may well be that the overall energy inputs will exceed the energy in the natural gas recovered and only fracking for "wet" gas (with NGLs) and oil will be viable.

US practice

The reason fracking got away in the US is because Dick Cheney brokered a "holiday" from EPA regulation by freeing it from the Safe Drinking Water Act. (The so-called "Halliburton Loophole"). The horrific consequences for water resources are now evident, but the industry is resisting tighter regulation and states have banned local fracking bans.

Conclusion

The failure to nominate suitable wastewater treatment facilities in the UK has created an impasse for fracking test drilling as there may be no means of disposing of the occurring wastewater. The energy requirement for the treatment of the high total dissolved solids and the associated transport and disposal options may exceed the energy content of the gas produced.

Tight regulation will mean that fracking for gas in the UK will be uneconomic, ruling out the Bowland-Hodder shale which principally contains just gas.

It means more intensive surveying in order to locate occurrences of "wet" gas with natural gas liquids and ethane or oil.

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