Everything you always wanted to know about acidising

Paper prepared for the Weald Action Group (a strategic umbrella for community groups across the region)

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Introduction

Fracking is in the limelight. But lime is an issue too, as are the acid techniques used to dissolve it to release oil or gas.

Within the gas-and oil-bearing shale across the UK are layers and pockets of 'impurities', limestone here, sandstone there. For example, deep below the Weald Basin in South East England, beneath Hampshire, Sussex and Surrey, a few thin, muddy limestone layers cut through a deep bed of shale. Back in the geological mists, oil formed in the shale, and some of this oil migrated into the pores within the limestone, and then became trapped there, barely able to move because the pores were no longer interconnected.

In South East England there is thus oil to be had from the plentiful shale, but also from these small limestone deposits within it.

To release its oil or gas, shale has to be fracked – cracked open. Limestone can be fracked too. But limestone can also be dissolved using acids – this is known as **acid stimulation, acidising or acidisation**. The word 'fracking' has become politically charged, a PR vexation for government and industry. But by drilling sideways not into the shale but into the limestone impurities, oil companies can claim that they will not frack (which is true, at least at the outset). What's more, it's way easier to drill into muddy limestone than into brittle shale. The limestone may be only a few metres in thickness, but acidising it at exploratory stage will give a very good idea about the amount and quality of oil present in the plentiful shale above and below.

Only later, at production stage, will oil and gas companies likely apply to frack. The planning and permitting systems in the UK are set up to facilitate this kind of 'development-by-stealth' in that only the current stage of a development can be considered.

Like fracking, acidising requires the drilling of a very large number of wells because the rocks are of low permeability. UKOG CEO Stephen Sanderson has explained to shareholders that acidised wells would, like high-volume hydraulically fracked wells, will need to be drilled 'back to back' at regular intervals across the Weald to access as much as possible of the oil – since the oil will flow only from the 'stimulated' parts of the rock near the wellbore. This proliferation of wells, industrialisation of the countryside, is one of the main reasons to oppose unconventional drilling.

Acidising is not new. But like fracking, acidisation is now planned on a far bigger scale, down long, horizontal wells. There are likely to be at least eight wells on each site or 'pad', with pads spaced every few miles.

Most of the negative arguments against fracking can also be made against acidisation – plus many more for 'stimulation' with hydrofluoric acid, one of the earth's most dangerous chemicals. As with fracking for shale gas, there are implications for human and animal health, environment and climate. Chemical use is even greater in acidisation than in hydraulic fracking. Solid and liquid waste will be toxic, highly saline and radioactive, a risk to groundwater, surface water and soil should accidents occur. There will be noise and light pollution and traffic, potentially carcinogenic air pollution from flares, potential water pollution via faults, fractures and the well bore, the risk of spills and other accidents. Storm and floodwater may spread pollution. Wells may be acidised repeatedly. There is little research on the subject of repeated acidisation and the cumulative effect on our environment and human health. On-site workers and local communities are particularly at risk.

Acidising can be done at low pressure, or, like fracking shale, at major pressure that fractures the rock. Not so long ago this would have been called an 'acid frack', but the Westminster government re-defined fracking in 2015 on the basis of the amount of fluid used rather than rock-cracking pressure. Acid fracking typically uses perhaps a tenth the amount of water compared with fracking. So now acidising slips under the fracking radar. Of oil wells that have been fracked in the USA, almost 90 per cent would not be considered to have been fracked under current UK law, along with 44 per cent of US-fracked gas wells (Stuart Haszeldene, University of Edinburgh).

4B Section 4A: supplementary provision

(1) "Associated hydraulic fracturing" means hydraulic fracturing of shale or strata encased in shale which—

(a) is carried out in connection with the use of the relevant well to search or bore for or get petroleum, and

(b) involves, or is expected to involve, the injection of—

(i) more than 1,000 cubic metres of fluid at each stage, or expected stage, of the hydraulic fracturing, or

(ii) more than 10,000 cubic metres of fluid in total.

Source: UK Infrastructure Act 2015

If it’s not officially fracking, none of the new rules and regulations developed by government under oil and gas industry guidance will apply – so oil companies will feel free to seek permissions to drill and acidise in National Parks, Sites of Special Scientific Interest, Areas of Outstanding Natural Beauty and so on, at depths of less than 1,000 metres, without any of the baseline monitoring prescribed for fracking.

‘Acid fracking’ is not the only expression government and industry are keen to avoid in their attempt to make this extreme form of oil and gas extraction a non-issue for public, planners and press. There is also a game of words around the terms ‘conventional’ and ‘unconventional’. There are no statutory definitions for these terms, but English National Minerals Planning Guidance in 2014 defined ‘conventional’ hydrocarbon sources as *any* oil or gas-bearing limestone or sandstone. ***This is incorrect**.* Geologists and engineers use the term ‘conventional’ to describe a geological formation from which oil or gas flows easily at commercial rate. ‘Conventional’ formations are permeable, so that one well can drain the rocks over a wide area. In ‘unconventional’ formations, the oil or gas remains trapped in minute globules within the rock until ‘stimulated’ or released, by fracking, acidising or other means. ‘Unconventional’ formations are also known as ‘tight’ formations. At Balcombe and Horse Hill, for example, in Sussex and Surrey, the micrite (muddy limestone, calcareous mud, Kimmeridge limestone) is ‘tight’.

Ernst & Young’s report of April 2016 for UK Oil and Gas (UKOG) on Kimmeridge Limestone explained:

> *“Kimmeridge Limestone Oil likely requires “stimulation” to flow to the surface at commercial rates. The primary stimulation method for wells in limestone rock formations is acidising.”*
>
> *— 'Kimmeridge Limestone Oil - The UK opportunity'*

Yet the government had declared all the PEDLs across the Weald to be ‘conventional’ when the announcement of the 14th round of new petroleum exploration and development licences was buried in the Christmas wrapping paper of 2015. Meanwhile, oil and gas companies call their ‘prospects’ in the Weald ‘unconventional’ when talking to potential shareholders, but imply that they are ‘conventional’ when speaking to local communities. UKOG’s well at Horse Hill, the Gatwick Gusher’, probably ‘gushed’ because they drilled into a fault zone – the rock around faults will have been naturally fractured by the geological trauma that formed the fault.

The British Geological Survey (BGS) has agreed that the definition of ‘conventional’ hydrocarbon sources as anything in limestone or sandstone is incorrect. The documentation of the Oil and Gas Authority (OGA) uses a Canadian diagram showing that both sandstone and limestone can be ‘unconventional’ (see below).

Fracking seemed enough to get our heads around. But the general public, campaigners, planners, water companies, politicians and regulators now all need to put acid on their agenda. They should also think critically ahead and understand that, although initial planning applications may seek to acidise at below fracturing pressure, production stage will almost certainly require acidisation at pressure sufficient to fracture the rock. And in the case of the Weald, further production may reach out into the shale that surrounds the muddy limestone (aka micrite or Kimmeridge limestone).

Planners and councillors are already facing decisions on applications for acidisation, yet they don't, for the most part, understand the science and the risks, nor the likelihood of proliferation - the very large number of wells that could be drilled. The oil and gas industry seems to do its best to confuse with obscure wording in planning applications. Planning applications may not mention acidising by name. 'Well stimulation' sounds rather friendly. UKOG's application at Markwells Wood in Sussex called it 'a new non-massive fracking-based reservoir stimulation technology that does not involve massive hydraulic fracturing'!

A 2018 Q&A document on acidising by the Environment Agency only begins to address the issues, leaving much open to interpretation, making light of the risks, and boasting of the Agency's ability to regulate, monitor and apply sanctions.

Few studies have addressed the potential problems. In the UK there has been little regulation or oversight.

The following is a detailed study of acidising, based on scientific papers, industry training manuals, promotional literature for new, patented technologies, and discussions with engineers, geologists and scientists.

Acidising, or acidisation

Acidisation is one of several techniques used to release 'tight' oil and gas – oil and gas that trapped in the tiniest droplets within rocks and unable to flow out at commercial rates unless 'stimulated' by fracking and/or acidising.

Almost two-thirds of the world's remaining oil reserves lie trapped in 'tight carbonate reservoirs' – strata that are rich in limestone (calcium carbonate) or dolomite (calcium magnesium carbonate). The Weald Basin across South East England has deep oil-bearing shale beds through which run layers of limestone-rich mud. Oil migrated long ago from the shale below into the limestone, where it remained trapped by a ceiling of shale above. The carbonate was then compressed by increasing layers of rock above, and held tight by underground stresses, so that pores and cracks (natural fractures) in the rock shrank and tightened, no longer allowing the oil to move around.

While shale is seriously impermeable and must be cracked apart (fracked, hydraulically fractured) by high-pressure water to release its oil, many carbonate formations can be made to flow by dissolving narrow pathways through the rock using acid solutions, sometimes under pressure strong enough to fracture the rock, sometimes not. Sandstone that fails to flow sufficiently can also be acidised – in this case the acid targets impurities within the sandstone.

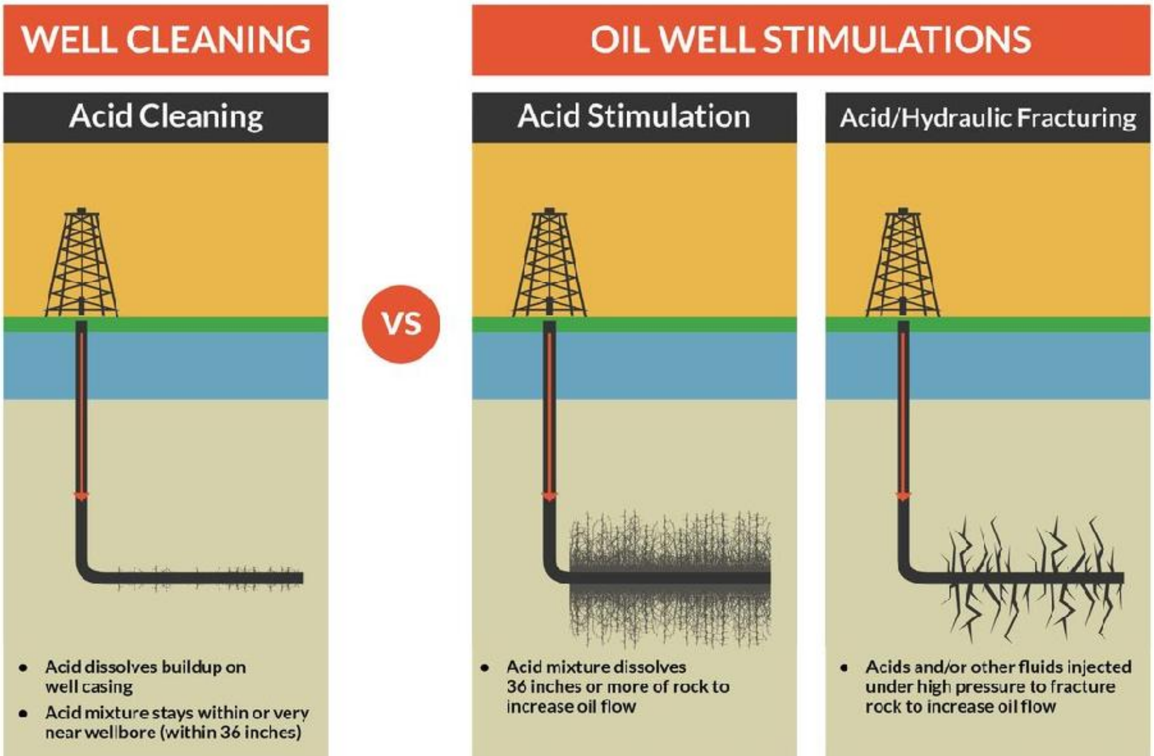
According to the training pages of *Rigzone*, an online information service for the oil and gas industry worldwide, 'Acidizing the well is employed to improve permeability and production rates of tight gas formations. Acidisation involves pumping the well with acids that dissolve the limestone, dolomite and calcite cement between the sediment grains of the reservoir rocks. This form of production stimulation helps to reinvigorate permeability by reestablishing the natural fissures that were present in the formation before compaction and cementation.' (Cementation is when small natural channels in the rocks get thoroughly blocked by the stuff of ages so that fluids can no longer flow through them.

Oil companies in the Weald have recently been keen to trumpet the fact that sampling and testing has shown the Kimmeridge limestone or micrite around their wells to be 'naturally fracked'. This should have been no surprise. It all is. But that doesn't mean that it will flow naturally.

From acid wash to acid frack

In the UK there are no statutory definitions of the three 'severities' of acidising – acid wash, matrix acidising and acid fracking - although in February 2018 the Environment Agency published its rather vague take on the subject in response to 'enquiries from the public and partner organisations'.

Companies applying for planning permission to acidise may not choose to explain exactly where on the scale their plans might lie. There are causes for concern at each level (acid use, other chemical additives, transportation, health hazards for workers, communities and environment…) – and the cumulative effect of many treatments.



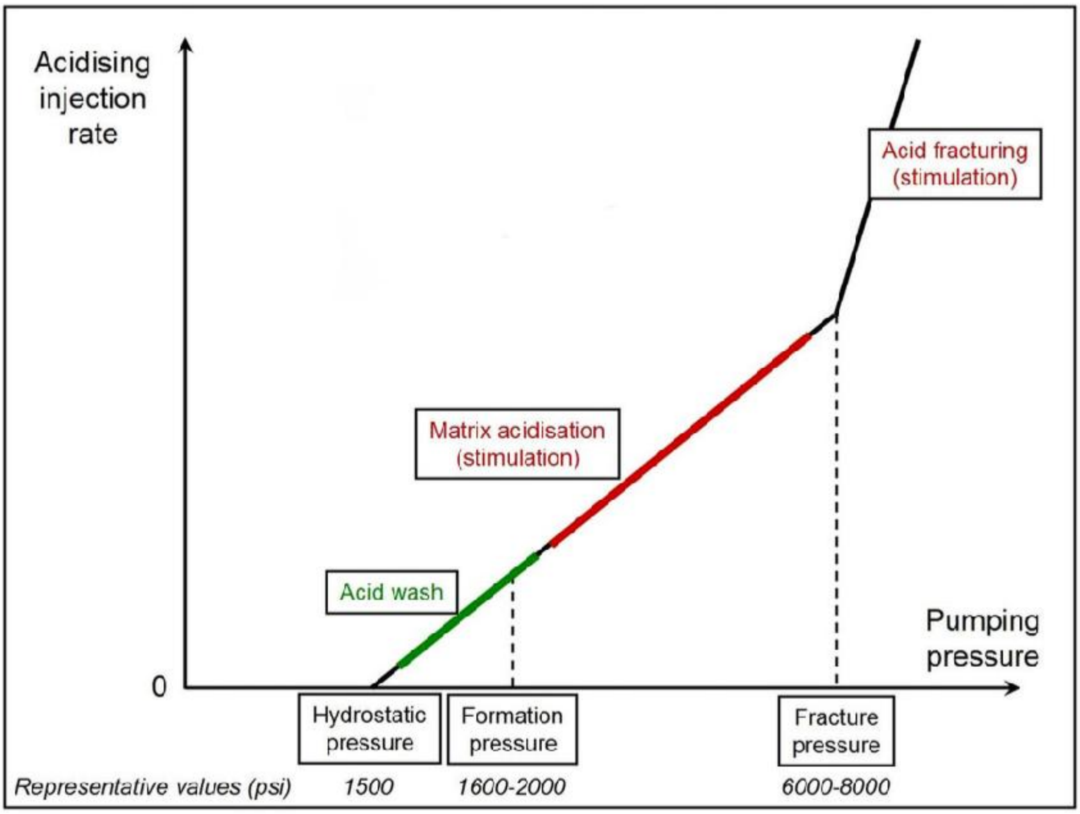
Source: Conservancy of Southwest Florida

1. ***Acid washing/acid maintenance*** is in theory cleaning the well at low pressure, usually with a weak hydrochloric acid solution plus additives, to get rid of debris, rust or scale so that oil and gas can flow freely into the well. This is how the industry has normally defined it, restricting the term more or less just to the well bore. Recently, however, the State of California defined an acid wash as up to 36 inches (nearly a metre) into the rock formation, and Florida is about to follow. This rather conflates it with the next category, matrix acidising. The Environment Agency in the UK has suggested that an acid wash generally uses a 7% solution of hydrochloric acid. However, recent UK applications for 'acid wash' have proposed using 10 to 15% solutions of hydrochloric acid.

2. ***Matrix acidising,*** which is a more invasive operation, is generally used for well testing, or in more permeable rock to free up the immediate surrounds of the well, to clear blockages and allow the oil to flow. 'Matrix' means the environment close to the well. It is done at low or lowish pressure (below the pressure at which that particular geological location or 'formation' would fracture – which will vary depending on local conditions). The acid solution would typically penetrate between a few inches and 5ft (a few centimetres to 150cm) into the surrounding rock, but occasionally in carbonate-rich rock it could travel 20ft (around 6m), creating small channels known as 'wormholes'. Higher concentrations of acid are used for matrix acidising than for acid washing – the solution would typically contain 18 per cent of chemicals, 15 per cent of which would be acid. Sandstone is much harder to dissolve, and matrix acidising of sandstone would affect a smaller diameter from the well, maybe 1 to 2ft (0.3 to 0.6 of a metre). In sandstone, the plan may be to dissolve particles of clay, feldspar or quartz within the sandstone to make or improve pathways for oil or gas. It is hard to believe that matrix acidising would make sufficient difference in a seriously 'tight formation' to allow viable production – but it would be enough at flow-testing stage to give companies an idea of how well a formation might flow if later acid fracked. The Environment Agency considers this to be a form of acid stimulation.

3. ***Fracture acidising/acid fracking/acid fracturing*** – this is a major operation, for less permeable rock, usually carbonate, done at a pressure above the fracture point of the rock, and using considerably more chemicals than in hydraulic fracturing of shale. While frack fluid for shale may be 99.5 per cent water, an acid frack solution will typically contain 17 per cent of chemicals, according to Khadeeja Saba Abdullah of the University of California, Los Angeles: perhaps 8 per cent acid, 9 per cent other additives. Acid fracking, she says, uses more water than matrix or maintenance acidising, maybe as much as 700,000kg per treatment. The aim is to dissolve the rock or components of the rock with some force, and penetrate much further into the formation. Length of fractures would typically be 50 to 100 feet (15 to 30 metres), in exceptional cases a few hundred feet (maybe 100 metres), in any case, not very far. This underlines the important fact that acid fracking (like fracking shale) requires a multiplicity of wells if a company wants to reach all parts of its licenced area. According to Schlumberger (a leading provider of technology and products to the oil and gas industry): 'Acid fracturing is a hydraulic fracturing treatment performed in carbonate formations. The objective is to 'etch' the open faces of induced fractures using a hydrochloric acid treatment. When the treatment is complete and the fracture closes, the etched surfaces provide high-conductivity flow paths from

the reservoir to the wellbore.' Because 'etched' by the acid, acidised fractures in carbonate formations do not need to be held open with 'proppants' such as sand or tiny ceramic balls. The process may need to be repeated, many times over, to keep the well flowing. The formation may be pre-treated with gels – see 'New technologies' below.



Different rocks, different acids, or mixes of acids

Put over-simply, hydrochloric acid is used on carbonate formations, hydrofluoric acid on sandstone formations. Geological formations are unlikely to be pure carbonate or pure sandstone. They may be mixed with clay, quartz, impurities various. And combinations of acids sometimes work better than one alone. So on a carbonate-rich formation, hydrochloric acid may be supplemented with sulphuric acid and/or organic acids: citric acid, formic acid or acetic acid. On sandstone the main acid used is hydrofluoric acid but this is often used in combination with hydrochloric acid – the mix known as 'mud acid'. Acidising sandstone 'formations' with hydrofluoric acid is not guaranteed success – one industry training manual suggests companies might expect an increase in flow of oil or gas in only a quarter or half of wells acidised with hydrofluoric acid. A hydrofluoric acid 'job' might give rise to precipitates that block the pores or fractures in the rock, especially when a lot of clay or more than ten per cent of carbonate is present in the sandstone. Pre-flushing with hydrochloric acid can pre-empt this problem. The proportion of acids used and their strengths depend partly on the temperature at the bottom of the well – it's hot down there! At 'low' 'bottom hole' temperatures – below 93°C, acids can penetrate deeper.

Acids containing hydrofluoric acid should not be used in carbonates or limey sandstones. On contact of hydrofluoric acid with limestone, a precipitate of calcium fluoride is immediately formed, which can block pathways and prevent hydrocarbon flow. In sandstones with low calcium content, a hydrochloric acid pre-flush is done before the hydrochloric/hydrofluoric acidisation.

Hydrofluoric acid – potentially catastrophic

Hydrofluoric acid is one of the most dangerous chemicals on earth. Undergraduate students are not allowed to use it in the lab. Its use presents a high risk for site workers, chemical workers and drivers, and for nearby communities, should there be an accident or blowout.

But there is little track record of use of hydrofluoric acid in the oil industry in the UK. In July 2016 the Environment Agency replied to a Freedom of Information Request from Helz Cuppleditch of Sussex as to 'how many onshore hydrocarbon (oil or gas) exploration and/or production sites under your jurisdiction have used hydrofluoric acid?' They admitted: 'The information you have requested is not held by the Environment Agency.'

When the British government was establishing 'Standard Rules' for onshore oil and gas planning applications – aspects and substances that could be nodded through planning without scrutiny – hydrofluoric acid was on the originally proposed list. It is thought that an intervention by Professor Lawrence Dunne, a resident of Balcombe, Sussex, resulted in its being removed from the final Standard Rules. Hydrofluoric acid is now beginning to appear in planning applications – for example for use in the sandstone formation in Wressle, North Lincolnshire. It may be listed as a proprietary brand, or the company may name compounds that will react down the well to produce hydrofluoric acid. It is vital to ensure that no loopholes are created for the oil and gas industry around the use and transport of hydrofluoric acid and its precursors.

In America the steel workers' union USW are campaigning to have the use of hydrofluoric acid banned in oil refineries. Their paper *A Risk Too Great* explains: 'If released into the atmosphere, hydrofluoric acid rapidly forms dense vapor clouds that hover near land and can travel great distances. Like other powerful acids, hydrofluoric can cause deep, severe burns and damage the eyes, skin, nose, throat and respiratory system. But the fluoride ion is also uniquely poisonous.

Entering the body through a burn or by the lungs, it can cause internal damage throughout the body. At high enough exposures, HF can kill.'

Harvard University's *Guidelines for the Safe Use of Hydrofluoric Acid* goes into further detail on its toxic effects: 'Fluoride poisoning is associated with hypocalcemia (low calcium levels), hyperkalemia (high potassium levels), hypomagnesemia (low magnesium levels), and sudden death. Systemic hypocalcemia should be considered a risk whenever the body surface area of skin burns from concentrated HF exceed the size of the palm of your hand. Concentrated HF burns can be fatal if only 2% of the body surface area is exposed. HF contact with the eye can cause eye burns and destruction of the cornea. Blindness results from severe or untreated exposures… Inhalation of HF vapors may cause "laryngospasm, laryngeal edema, bronchospasm and/or acute pulmonary edema.' Initial symptoms include coughing, choking, chest tightness, chills, fever, and blue skin. Deep ulceration may lead to gangrene.

Hydrofluoric acid can be transported by road in specially constructed, dedicated tankers, or it can be made within the well. If hydrofluoric acid were transported on our busy roads and motorways, through densely populated towns and villages, accidents and spills could be catastrophic. The transportation of hydrofluoric acid is tightly regulated, with a standard warning code, but incidents are rare, so hospitals, fire crews and other emergency response teams would not necessarily know the implications. For instance, if the wrong chemicals were used to neutralise the acid, the consequences could be devastating for nearby people, animals and the environment generally. The topsoil would have to be removed to a hazardous waste landfill. One engineer commented: 'It's not the sort of load you want going down country lanes and having to reverse when it meets a Range Rover plus horse trailer coming the other way!'

Professor Dunne has many concerns about the use of hydrofluoric acid for oil exploration and production: 'The oil and gas industry has huge experience in this country of using hydrochloric acid,' he says, 'but hydrofluoric acid is in a different ballpark. What studies have been done to determine the radioactive flowback components from formations washed with hydrofluoric acid? Hydrofluoric acid is very different and much more potent that hydrochloric acid. Hydrofluoric acid will extract the radioactive uranium in the well as well as uranium hexafluoride in the returned acid wash. Both are lethal substances. How will they be dealt with? We know a great number of cancerous toxins enter the air through flaring. What are the implications for air pollution of a well having been acidised? What training will the well crews and the emergency services have in working with hydrofluoric acid?'

Blowouts

This is a worst-case scenario. A blowout involving hydrofluoric acid would be catastrophic for workers as well as for communities. A 'blowout' is an out-of-control gushing-up of fluids and gases from a well after pressure-regulating systems have failed. Blowouts can happen at any stage from drilling onwards. 'Gushers' were a regular feature of oil and gas drilling until pressure control equipment began to be developed in the 1920s. They are rarer nowadays – modern wells have blowout preventers or BOPs, essentially large valves at the wellhead. But blowouts still happen.

Deepwater Horizon in the Gulf of Mexico and the 2012 Elgin blowout in the North Sea are recent examples. As there are generally warning signs, human error or negligence is usually to blame. (Total were fined a measly £1.125m for their Elgin blowout, and most of the press called it a 'leak' – see below a link to a fascinating letter from an Elgin rig worker at the time of the Balcombe protests.) Professor Dunne has concerns over whether the material in the neck of a blow-out preventer would be resistant to attack from hydrofluoric acid. An accidental spark during a blowout can lead to a catastrophic oil or gas fire. Accident response teams sometimes *choose* to set fire to the escaping gases and fluids, especially if hydrogen sulphide is present, tossing up whether the escapee chemicals themselves are more toxic than their combustion products.

It's a fair guess that in April 2014, a blowout following a hydrochloric 'acid job' resulted in a cloud of nebulised hydrochloric acid near the village of Wittorf in Lower Saxony, North Germany. Exxon Mobil admitted that they had to flare off gas 'for technical reasons'. Local people reported a cloud of what looked like steam and 'terrible smells' around the Söhlingen Z5 well. People even a few kilometres away experienced breathing difficulties, coughing, headaches, red and streaming eyes, inflammation and bleeding pores, burning skin and general malaise. Some were treated in hospital. This was hydrochloric acid; hydrofluoric is far more dangerous.

Is acidising new?

Oil and gas prospectors experimented with acidising in the late 19th century, but it was only in the 1930s that it became of practical use, when corrosion inhibitors were developed to prevent damage to metal well casings. Especially when hot, acid can attack well casings aggressively, and the deeper the well, the hotter it's likely to be at the bottom. The acid solution may nowadays be pumped down a coiled tube inserted inside the well casing.

What *is* new, since the mid-1990s is acidisation *in long lateral wells*. As with high volume hydraulic fracturing (the now famous and infamous fracking of shale formations) there has been *a change of scale* – like the difference, as oil and gas engineer Mike Hill says, between a corner shop and a hypermarket. Since the advent of horizontal drilling, oil and gas companies are now able to 'get up close', to a much higher proportion of a target formation all the way along their horizontal boreholes.

Investigating individual wells around Britain, it is alarmingly unclear where and how much acid stimulation has been used in the past – including in 'conventional' wells. Freedom of Information requests to the Environment Agency have revealed that they kept little or no data prior to 2013 on transport and use of acids and other chemicals for use in 'acid jobs'.

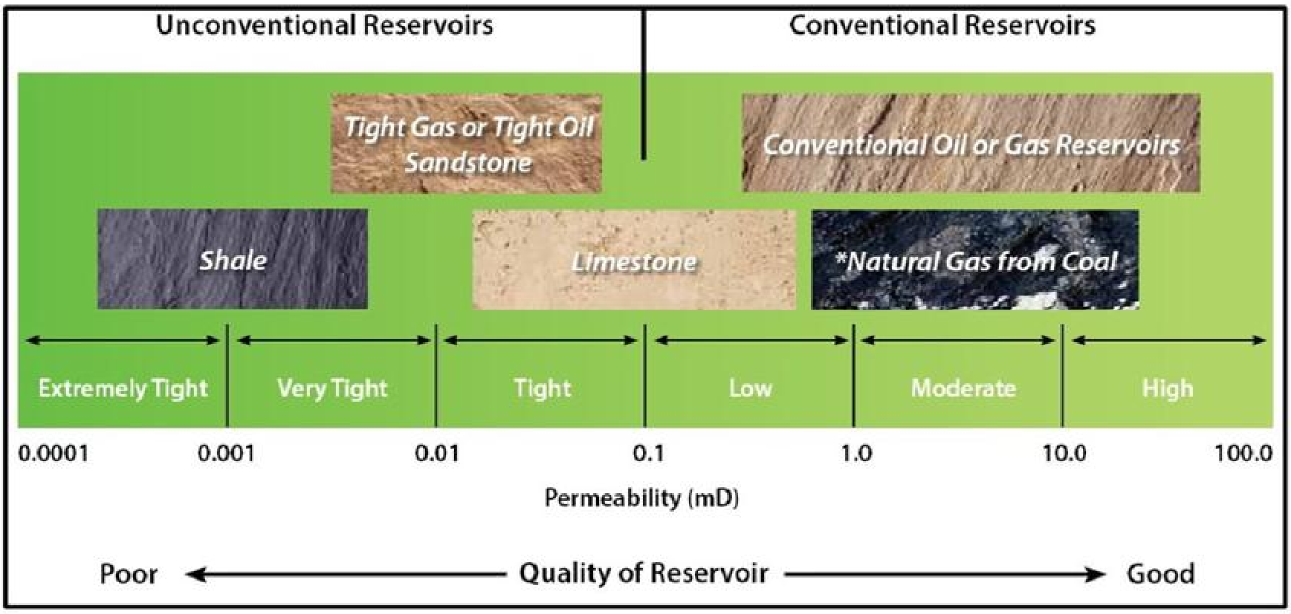
Is acidising 'conventional'?

Geologists and the oil and gas industry use these terms to distinguish *geological formations* targeted for oil and gas production. Whether the formations are classified as conventional or unconventional depends on the ease with which oil and gas flow through them.

In recent times, however, the terms conventional and unconventional have been loosely applied to *techniques*, such as fracking, acidising, underground coal gasification and the extraction of coal bed methane as well as to the ‘conventional gas’ or ‘unconventional oil’ that might result.

And in March 2014, the Department for Communities and Local Government wrongly defined ‘conventional’ in its minerals planning guidance (PPG) as any sources of hydrocarbons in limestone or sandstone. Actually the Department of Energy and Climate Change (DECC) inserted this definition, which is clearly simplistic at best. The British Geological Survey disagrees with the definition, as does the Oil and Gas Authority (OGA).

Below is an illustration from a document published by the OGA, showing that sandstone and limestone can sometimes be permeable and sometimes less so, sometimes conventional and sometimes unconventional.



The distinction is generally accepted by geologists and other scientists to pivot on the permeability of 0.1 milliDarcies.

In true conventional formations of good permeability, oil or gas migrate upwards or sometimes laterally until either they reach the surface or become trapped under impermeable rocks, often in a dome or fault above or alongside porous ‘reservoirs’. Once a well is drilled, ideally into the ‘dome’, the oil or gas can flow through the permeable, porous rock and up the well at a commercially viable rate.

Formations that do not flow easily are known as ‘tight’, and ‘unconventional’. The Upper Jurassic carbonate strata of the Weald (such as the muddy limestone/ micrite/Kimmeridge limestone at Balcombe and Broadford Bridge) is highly unlikely to flow at an economic rate without ‘stimulation’ (acidising and/or fracking). These formations are unconventional, even if our government and PR-minded oil men choose to call them conventional.

The situation is less clear in the Weald in wells drilled into the deeper, oolite limestone. This was laid down in the Lower Jurassic period, long before the micrite. Oolitic limestone is composed of tiny spherical 'ooliths' formed when calcium carbonate precipitated around grains of sand in warm lime-rich seas – think pearls. Imagine marbles in a jar – there will always be spaces between them. So oolitic limestones in their original, pristine state flow freely. But in some places, loose lime may have welded up some or most of the gaps, and these 'naturally cemented' beds are less likely to allow fluids to flow, unless acidised. The historic, isolated, 'conventional' wells of the Weald, Singleton, Horndean and the like, drilled into free-flowing 'sweet spots' in the oolite, have always been termed 'conventional'.

When the Government allocated its 14th round of Petroleum Exploration & Development Licences in 2015, all the licenced areas across the Weald were officially but falsely labelled in the spreadsheet as 'conventional' – based on the incorrect definition in national planning guidance. UKOG, who drilled the so-called 'Gatwick Gusher' into the micrite at Horse Hill in 2016, insist to the public that the well is conventional but talk of 'unconventional plays' to their shareholders.

This appears to be a semantic game to make the looming large-scale oil exploration across the Weald appear to be cosy, old-fashioned, and nothing whatsoever to worry about.

The true, new objective across much of the Weald is to extract oil from tight, unconventional formations.

Getting the measure of tight oil and gas

Oil flow through rock (the formation's permeability) is measured in Darcies and milliDarcies – see diagram above. (French water engineer Henry Darcy may be turning in his 19th century grave.) *Rigzone* helpfully explains that 'a Darcy is the permeability that will allow a flow of one cubic centimetre per second of a fluid with one centipoise viscosity (resistance to flow) through a distance of one centimetre through an area of one square centimetre under a differential pressure of one atmosphere.' Mr Darcy was not just a handsome chap.

It is important to distinguish between porosity and permeability. A formation can be porous but not permeable. To be permeable, liquids and gases need to be able to flow, through pores, fissures or 'joints', interconnections between pores. Take the muddy limestone/micrite/Kimmeridge limestone, current target of various companies across the Weald. Micrite is an extremely fine-grained limestone made up of minute algal remains whose pore spaces are 'less than a tenth of a sand grain' in size. In Balcombe and Horse Hill these tiny pores are filled with oil. The micrite is very porous, but because the pores are so small and poorly interconnected, the permeability of the micrite is low.

According to geologist Dr Ian West of Southampton University, 'Porosity is the percentage of pore space. Permeability is the extent to which fluids can flow through the rock. If the pores are very small, in spite of good porosity, then the fluids cannot flow easily. Conventional production of oil or gas involves flow of fluids through large interconnected pores. Unconventional production opens up spaces for the fluids to flow when the permeability is very low because of the minute sizes and lack of connection of the pores.' In the olden days, he says, fine-textured rocks of low permeability were not used for oil and gas production.

How concentrated is the acid treatment?

It depends on the situation and the objective. New, gel-based technologies can reduce the amount of fluid used (see below). Hydrochloric acid could be used at up to 28% but typically concentrations are up to 15%, while hydrofluoric acid is used at much lower concentrations, 0.5 to 3%. Recent planning applications have chosen vocabulary such as 'low volume' and 'non-massive', presumably eager to slip beneath the government's new definition of fracking in the Infrastructure Act. Fracking has been legally defined in the Act by the amount of water used (over 10,000 cubic metres per well, over 1,000 cubic metres for each section), whereas *as any fule kno* fracking is more about pressure than volume – the pressure at which the fluid fractures that particular rock formation.

What happens to the acid underground?

In carbonate formations, hydrochloric acid reacts quickly with the rock to form salt, water and carbon dioxide. The reaction is not always complete (see below).

In sandstone, the reaction with hydrofluoric acid is more complex. According to The American Petroleum Institute, the reactions happen in three stages: 'In the primary stage, the mud acid reacts with the sand, feldspar and clays to form silicon fluorides and aluminum fluorides. In the secondary stage the silicon fluorides can react with clay and feldspar to release aluminum and silicon precipitates, however with proper design, formation of these damaging precipitates, which can restrict flow of oil or gas through the formation, can be avoided. In the final stage the remaining aluminum fluorides react until all the remaining acid is consumed.'

Most of the acid is consumed down in the rock. But care has to be taken with the flowback water from an 'acid job'.

Flowback

The American Petroleum Institute again: 'After the acid job is successfully pumped and the well is brought to production, the operator should consider using separate tanks or containers to isolate the initial produced fluids (spent acid and produced water). The fluids that are initially recovered will contain the spent acid (acid that is largely chemically reacted, neutralized, and converted to inert materials) and it will typically have a pH of 2-3 or greater, approaching neutral pH. These fluids can be further neutralized to a pH>4.5 prior to introduction into the produced water treatment equipment, if necessary. Once neutralized, the spent acid and produced water can be handled with other produced water at the production site. Most produced water, including spent acid, is treated as needed and then injected via deep injection wells that are permitted by the jurisdictional regulatory authority.'

As with flowback from shale fracking, the fluids returning from an 'acid job' will contain not only chemicals and reaction products of chemicals injected in the treatment fluid but also substances released from the formation: brine, salts of heavy metals, radioactive materials (uranium as well as uranium hexafluoride in the case of a hydrofluoric acid 'job'). As with shale fracking, it will be a big headache disposing of this flowback and 'produced water'. (Produced water is contaminated water released from the formation, which in practice is mixed in with the flowback, at least in the early stages). Treatment of this liquid waste is difficult and costly, so likely solutions are a) partial treatment in an industrial-level water treatment plant and then mixing it with other effluent so that the levels of contaminants in the final mix fall below levels considered toxic (a challenge in the case of some heavy metals where permitted discharge levels are very low), and then dumping the mix at sea; or b) injecting it into wells, either specially drilled or pre-used as production or exploration wells. Treatment is particularly difficult and expensive because of the high salinity, possible radioactivity and the probable presence of salts of a variety of heavy metals.

There are states in America suffering a high earthquake rate because of injection of fracking waste. Oklahoma used to have two earthquakes per year; now it has more than two per day. At Lidsey in West Sussex, the current application includes an injection well despite the fact that this highly faulted zone not far from Chichester, has, in the past, suffered earthquakes. Eight fault lines cross through the site and the major Bembridge Saint Valery fault line is close.

Maximising the economic recovery…

Acidising fluids will follow the path of least resistance, not necessarily the direction desired by the engineers. That may mean that the least permeable area doesn't get its fair share of the acid. Acid solution going astray is called 'leakoff'. Leakoff is avoided in various ways. Making the acid mix viscous slows the flow (see 'Other additives', below). Temporary plugs can be engineered into place. This is harder to do in long lateral wells. Chemical additives can also do the trick (see below). To avoid damage to the well casings by acid, coiled tubing is sometimes used down and along the wellbore to deliver the acid, and this can also help target particular sections of long, lateral wells. There are also newer technologies, such as gels and 'Fishbones' (see below).

Another potential problem is the creation of insoluble substances as a result of reactions between acids and constituents of the formation. These may block the pores and 'wormholes' in the rock, undoing the 'good' work of the acid or even making matters worse than before the acidising took place.

Sludges or emulsions may form if acid comes into contact with oil or other well fluids such as drilling muds. Additives are the answer.

Other additives

Many other chemicals may be added to an acid wash to avoid problems and maximise efficiency, the type and volume based on analysis of cores of rock taken while drilling, and then lab tests. Because the challenges are different in carbonate or sandstone formations and shale, the chemicals vary too. Some additives commonly used in frack fluids for shale may be unsuitable for an acidic environment. As with frack fluids for shale, acidising additives are sometimes mixed in anonymous proprietary brands, such as Protekt 7 or Protekt 15.

Listed here are some of the groups of additives:

- Various polymers (long chains of molecules that create a gooey, viscous texture) may be added, sometimes along with metallic salts, to increase the viscosity and slow the flow of the acid wash. According to PetroWiki: ‘Acids may be thickened for diversion during acidizing with soluble polymers such as xanthan gum (a biopolymer) or acrylamide polymers. Higher viscosity may be obtained with crosslinking metal ions or ligands. Certain surfactants may be used to thicken acid through the formation of surfactant micelles.’ (See below for further details and ‘a translation’.)
- Whatever the acid, corrosion inhibitors are needed to reduce damage by the acid solution to the well casings and other equipment both at the surface and in the well. Inhibitors are typically organic compounds that cling in a thin film onto metal surfaces. They are expensive but indispensable, even if not 100% effective.
- Chemicals may be added to deter ‘leakoff’ as an alternative to physical barriers (see ‘Maximising the economic recovery…’ above). Schlumberger propose the following: ‘…chemical diversion methods include nitrogen foam, bridging agents such as benzoic acid flakes, and cross-linked polymer gels. These create a temporary plug in high-permeability carbonate zones so that the stimulation fluids are diverted into the low-permeability zones that require more treatment.’ In gas wells, ‘foamed acid’ may be the best option as other additives may be difficult to clean out of the formation. (See ‘gels’ below for an explanation of cross-linking.)
- Detergents/surfactants/anti-sludge agents/solvents are needed to avoid the formation of unwanted gels, sludges, waxes and emulsions and prevent the added corrosion inhibitors from coating the rock formation.
- Iron control agents keep rust particles in solution (as ferric or ferrous ions). Iron and the compounds it forms are one of the big headaches in an ‘acid job’. Iron reducing or iron complexing agents include erythorbic acid, citric acid with acetic anhydride, and *nitrilotriacetic* acid.
- Hydrogen sulphide ‘scavengers’ in ‘sour’, sulphidy formations (as found in the Weald) remove hydrogen sulphide so that it cannot react with iron to form precipitates.
- Calcium sulphate inhibitors are used in formations where high levels of sulphate ions are present in the water within the formation, or rock containing anhydrite. These are usually phosphonic acid or polyacrylate.
- Possibly acetic acid in a pre-flush to prevent precipitation of iron carbonate.
- Alcohol at between 10 and 20% may speed the return of fluids out of the formation and up to the surface. Methyl alcohol or isopropyl alcohol are sometimes used.
- Clay stabilising polymers may be needed if the acid fluid is likely to disturb and move clay particles or cause them to swell and block passageways. These could be polyquaternary amines, polyamines or cationic surfactants.
- Biocides deter bacterial growth.

- A hydrofluoric 'acid job' may be preceded by a hydrochloric or citric acid pre-flush to dissolve carbonate, and/or it may be followed by an 'over-flush' of equal or greater volume than the main 'acid job' to clean out any remaining precipitates, fluids or other chemicals. *PetroWiki* (an info-sharing platform for the oil and gas industry developed by the [international] Society of Petroleum Engineers, SPE) gives an idea of possible chemicals in an overflush after a hydrofluoric acid treatment: ammonium chloride brine, weak acid (3 to 7.5% hydrochloric acid), filtered diesel oil or aromatic solvent (oil wells only) or nitrogen (gas wells only), ethylene glycol monobutyl ether (EGMBE) and a polyquarternary amine clay stabiliser.

Acid *fracking* (acidising at above the pressure needed to fracture the rock) is normally done without a proppant – the tiny particles injected with frack fluid when fracking shale to keep the fractures open. Proppants are usually a rare, spherical silica sand, or sometimes bauxite, or tiny aluminium oxide or ceramic beads. When acidising, the hope is that the pathways, wormholes and etched fractures will remain sufficiently open without the need for a proppant. If not, or if the 'acid job' does not result in an adequate flow, acid fracking may be followed by hydraulic fracturing.

Khadeeja Saba Abdullah, now Doctor of Environmental Science and Engineering, University of California, Los Angeles, focussed her dissertation in 2016 partly on this subject, concerned at how little was known about it given the increase in acidising in California over the past decade. Hers was the first study of the potential toxicological impact of acidisation. Similar chemical additives are used in acidising as are used in high volume hydraulic fracking of shale, she says, but the concentrations are much greater, and those used most frequently are different. 'There are close to 200 specific chemicals used in acidisation, with at least 28 of them being F graded hazardous chemicals. Some are used frequently in the range of 100 to 1,000 kg per treatment, such as hydrofluoric acid, xylene, diethylene glycol and ethyl benzene. Close to 90 more chemicals are identified using non-specific names as trade secrets or reported with no quantity. Unlike hydraulic fracturing, the chemical concentrations in acidising are high, ranging from 6% to 18%.'

These chemicals, she says, include neurotoxins, developmental or reproductive toxins, and carcinogens, and for many there is little understanding of their toxicity, the quantities used, and how much comes back in the flowback and produced water, whether the original chemicals, products of underground reactions or substances leached out from the formation.

Two heads are better than one

According to PetroWiki: 'Long treatments can best be controlled by two persons - one to coordinate the acid schedule and rate and pressure control, and the other to check materials, titrate acid and monitor volumes, rates, and pressures. The engineer who recommended and designed the job and the supervisor who prepared the well for acidizing make a good combination.'

New technologies – gels, squeeze frac' and acid squeeze

Gels have been used in frack fluids for shale and in acidising fluids since the 1980s to make the liquids more viscous – this slows down the acid reaction, making it more effective, allows the acid mix to be targeted more precisely at particular sections of the formation, and can enable the fluid temporarily to block existing channels and force it to make new ones. Gels are particularly useful in long, lateral wells, which are hard to acidise effectively with fast-flowing liquids. The R&D departments of companies such as Schlumberger and Halliburton have worked for decades on developing and improving gels and are still coming up with new proprietary brands with names such as Swellpac, Duofrac or Squeezefrac, some of which are now being proposed for use in Britain. Whether for matrix or fracture acidising, treatments are typically two-fold. Firstly a water-based gel mix (called a 'pad') is pumped into the well to swell and create fractures, and then the acid is pumped to etch the sides of the fractures. The acid fluid will also typically contain a gel, and may be referred to as a VCA or viscosity-controlled acid. Such gelled treatments can increase production enormously.

Gelling agents may be 'linear' (simple polymers made up of a chain of molecules), usually derived from plants such as guar gum (from a legume), carboxymethyl HPG (from wood), hydroxyethyl cellulose (from wood or other plants), or xanthan gum, a substance made when a certain bacterium ferments sugars, producing gloop. Gelling agents come as powders that swell when mixed with water. Some are used in the food industry. Some gelling agents are 'cross-linked'. This means that a chemical, typically borate ions, is used to link one polymer chain to another, to form a three-dimensional shape that is more 'elastic' and better able to hold solids in suspension. The borate link is strong in the original acid solution, but breaks down once the acid reacts with the formation, so that the polymers return to simple chain formation and the mix no longer blocks the passageways. Another recent development, Clearfrac, is a 'visco-elastic surfactant' containing no polymer.

These are the kind of 'new techniques' that were proposed by UKOG at Markwells Wood and by Egdon in North Lincolnshire. The language in the planning applications is vague. At Markwells Wood, for instance, UKOG's planning application talked of *'utilizing horizontal wells and new non-massive fracking-based reservoir stimulation technology that does not involve massive hydraulic fracturing ("fracking").'* 'Massive' is a formerly lesser-used industry term for high volume. Is it an acid frack? Is it a fishbone? Who can tell? (For fishbones, read on.)

The planning application at Wressle in North Lincolnshire (targeting sandstone) mentions a 'proppant squeeze'. Egdon Resources personnel, meanwhile, have name-dropped a proprietary brand called 'Duofrac' – much used in the USA in carbonate and sandstone wells, a gel and proppant mix, followed by gelled acid.

Texas fracking/acidising technology company EnerPol explain their pre-acidising mix 'SqueezeFrac' as follows: 'Small, solid particles of degradable polymer and proppant are pumped into the wellbore with water. Wait 2-6 hours for the polymer to degrade to a high-viscosity gel in the wellbore (heat + water cause degradation). Apply pressure at surface with small pump to 'squeeze' high-viscosity gel (with suspended proppant) into the formation (low velocity / high pressure). Within 1-2 days the polymer gel completely degrades, leaving the proppant in place and no residue on the formation.'

New technologies – 'Fishbones'

Fishbones is the name of a Norwegian oil and gas technology company and the method it has developed for delivering an apparently super-targeted 'acid job' in carbonate, sandstone or coal beds, using less fluid than a 'normal high volume hydraulic frack.

Into the well is inserted a tube incorporating valve holes (so that no in-situ perforation of the well lining by explosives is needed). Once the pipe is in place, 200 narrow-diameter 40ft/12m titanium needles jet out into the formation 'like the ribs of a giant fish skeleton', driven by turbines. At the tips are jet nozzles to deliver the frack fluid. According to the company, the equipment cuts fracking time from days to hours, uses ordinary rig pumps rather than banks of fracking pumps, fractures a greater radius from the well bore, and cuts water use and costs.

The company worked initially with Statoil, Eni, Lundin, Innovation Norway and the Research Council of Norway, and is now in league with ten major oil and gas companies including Total, Shell and BP. Norwegian oil and gas exploration and production company Aker BP bought a 17% stake in the company in December 2017, and intends initially to use it in the 'soft and fine-grained reservoir' of the Valhall chalk field on the Norwegian Continental Shelf, further developing the technology to suit those conditions.

The technology was first field trialed in 2013 in a coalfield in south Sumatra, then in 2014 in carbonate in Texas, and in 2015 in tight sandstone in the Norwegian Sea. Various producers in the Middle East have now bought the technology.

Fracking or acidising, both to be resisted!

Whether industry chooses to call the micrite acidising process conventional or unconventional, fracking or not fracking, acidised wells will need to be drilled 'back to back' across the Weald if companies are to exploit their Petroleum Exploration and Development Licences (PEDLs) to the full. ''You have to drill a lot of wells close to each other (…) almost back to back so that it becomes like an industrial process,' said Stephen Sanderson, CEO of UKOG (www.youtube.com/watch?v=5zBAD-EJHyk). You can almost see the thought bubble as he compares the Weald with the similar carbonate Bakken oil 'play' of North Dakota, which is fracked. Production from new wells is likely to slow rapidly, and the wells will need to be re-acidised, and new wells will have to be drilled. This would also be the case in 'tight', 'naturally cemented' oolite.

If things develop as the oil and gas industry desire, there will be hundreds of oil wells across the Weald; toxic, radioactive waste will be created, solid and liquid; and there will be all the local hazards and nuisances of fracking: noise and light pollution, air pollution, flares in early stages (with their dangerous emissions), traffic, the possibility of releasing treatment fluids or previously locked-in toxins into our water sources via the well bores, fractures or natural faults, and at point of disposal..

And the result will be 'extreme' fossil fuels, fuels that must stay in the ground if we are to avoid catastrophic climate change.

Comparing acidising of water wells to acidising oil or gas wells

Oil companies and their PR people frequently tell us that acidising oil wells is clearly no big deal because water well drillers do it all the time. That is not true, and anyway, there's a huge difference between acidising a water well and acidising an oil well.

We interviewed a water well drilling expert, and learnt that *acidisation is very rarely used in water wells.* What's more, cases where acidisation is used 'are getting fewer and farther between. Acidising would be used only when a very high-yielding borehole is required, when someone has a ginormous demand for water,' he said. 'Mostly the rock itself and its natural fracture systems are enough. When, rarely, we acidise, it is typically before the first pump test, after drilling, not to maintain or improve an existing well.'

If it is done, *no other chemicals are used* other than hydrochloric acid. For water wells, drillers are aiming for a straight, vertical borehole, never deviated, never lateral/horizontal as tends to be the case with modern oil or gas wells. The wells are lined with perforated plastic piping rather than steel, so corrosion inhibitors are not needed. *It is not done at pressure,* so this is not an acid frack or even matrix acidising. And water wells are typically much shallower than oil or gas wells, and of course drilled into a clean aquifer. Maximum depth a water well might be drilled to is '400 metres or more' but it's usually less. The deepest water well we know of in Sussex is 250m.

The acid solution is gently pumped down a straight pipe that they insert within the plastic lining of the well to the required depth. There will be a water column in the pipe, so they can't/don't need to block it off, although it is possible to use a 'grommet' a kind of balloon that they can inflate to block the pipe and confine the acid to the upper section that they want to acidise. They never use the gels and foams that the oil and gas industry sometimes uses nowadays to force the acid to flow to the precise target area of rock.

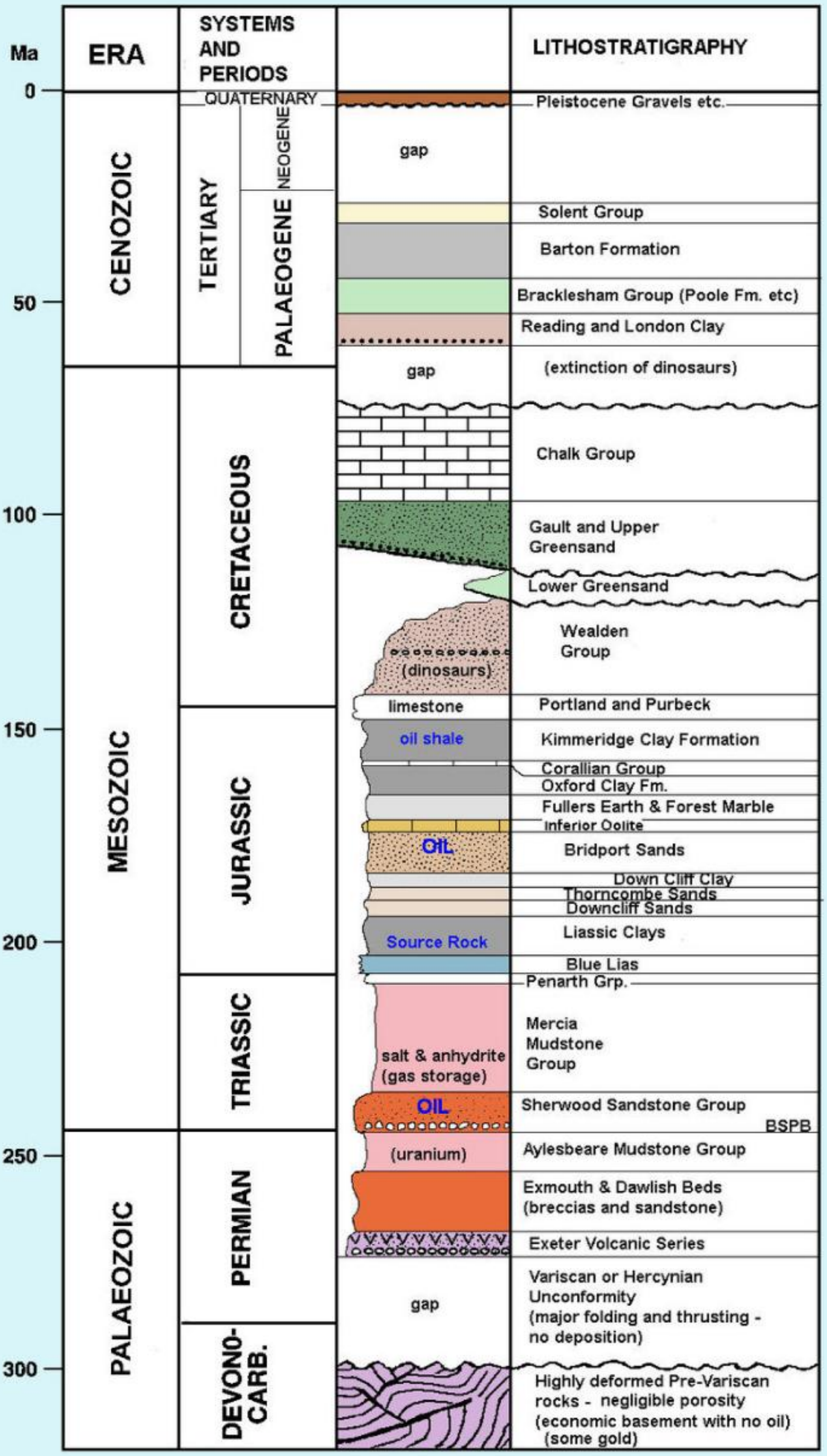
What flows back from an acidised water well is a diluted version of what went in - very dilute hydrochloric acid - but nevertheless workers have to wear appropriate protective gear and follow strict health and safety rules, and the water is tested again and again until it is utterly pure.

Oil and gas wells, by contrast, are typically drilled much deeper than water wells. They are drilled into hydrocarbon-bearing rocks, typically also a very salty environment. Numerous other chemicals are used in addition to hydrochloric acid, for example biocides, solvents, corrosion inhibitors, iron inhibitors… While an oil or gas company may in the first instance 'acid wash' their well and its immediate vicinity, exerting no pressure other than that supplied by gravity, at test stage they are likely to increase the pressure, and at production stage they are likely to acid frack at greater pressure. What flows back from an acidised or fracked oil or gas well includes reaction products of injected chemicals and the formation rocks, remnants of the injected chemicals, and substances released or leached out from the formation, including salts (perhaps five times the salinity of seawater), hydrocarbons, heavy metals and possibly Naturally Occurring Radioactive Materials (NORMs).

Acidising the Weald

The Weald basin stretches from Kent in the east into Hampshire in the west. Sediments deposited over the millennia have resulted in largely the same underlying layered geology across the region, limestones (calcium carbonate), sandstones, clays and mud rocks (shales), sometimes found at different depths because the earth moved and folded in millennia gone by. Some 70 million years ago, the rock strata were pushed and folded upwards in earth movements that also formed the Alps. In the Weald, the movement caused much crumpling and faulting. Emeritus Professor David Smythe has shown how these faults today could act as conduits for polluting liquids and gases (see below).

Organic-rich mudstone that at some stage has been buried deep and hot may have become 'thermally mature', and have generated oil within its hard, fine, fragile layers. Oil is most likely to be found within the shale in in an extended central area lying west to east across the Weald. Oil is still trapped in tiny particles in the shale, but at some point some oil may have migrated into thin, muddy limestone or sandstone layers above, only to be blocked there by a further ceiling of shale. The muddy limestone layers, normally called micrites by geologists and in recent times Kimmeridge limestones by the industry are currently the oil companies' target in the central part of the Weald.



GENERALISED STRATIGRAPHIC COLUMN FOR THE WESSEX BASIN.
Based on, but modified after, part of a diagram by Underhill and Stoneley (1998), with some additional notes. It is introductory and intended to show the main units of the sequence; it is simplified and is not accurate for detail. See other diagrams on particular parts of the stratigraphical column for specific zonal, lithological and thickness information. Ian West (c) 2010

Ian West (2010), based on Underhill and Stoneley (1998)

These are unconventional strata, needing stimulation, by acid and/or fracking – as at Balcombe and Horse Hill, Broadford Bridge, Brockham and Leith Hill. Writing before the recent industry enthusiasm about acidising the micrites, Southampton geologist Dr Ian West wrote: ‘Argillaceous coccolith micrites are not used as conventional reservoir rocks in general in southern England. Even if they have adequate porosity, the permeability in such a fine-grained rock would be remarkably low and unsatisfactory for normal reservoir purposes.’

Long ago, the micrite cracked under the pressure of the rock above, and during earth movements. Now pressure and stresses keep these natural fractures too tightly closed for oil to flow at a commercial rate – except, perhaps, in the immediate vicinity of faults. Above and below this micrite layer is shale, cut through a little deeper down by a couple of further thin bands of micrite. Producing from a low-permeability unconventional reservoir above oil shale in this way is known as ‘hybrid production’.

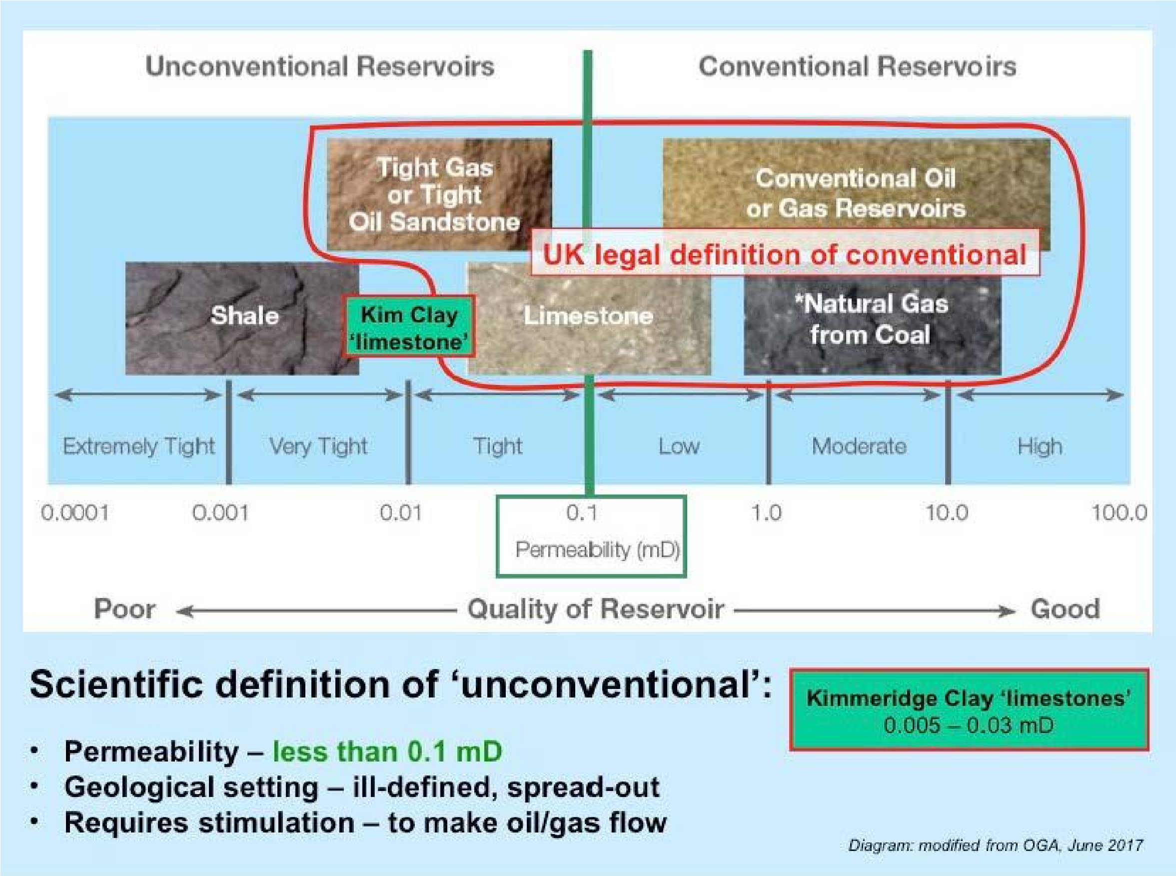
The other carbonate ‘prospect’ in the Weald is the Great Oolite, a much deeper limestone sedimentary layer of the Middle Jurassic period. Oolite is made up of particles that are more spherical and less fine-grained than micrite, so that the rock is potentially, but not always, more permeable. Indeed, the Great Oolite is the main conventional oil reservoir across the Weald – the conventional wells at Singleton and Storrington, for instance, in West Sussex, are drilled into the Great Oolite. Great Oolite was the target at Markwells Wood in the South Downs National Park, West Sussex, which was refused planning decision including acidisation early in 2017.

Conventional oil and gas wells in the Weald

Great Oolite is a minor source rock at Wytch Farm in Dorset, supposedly Europe’s largest onshore oil field, mostly drilled into permeable sandstone. (In fact, although the wells start on land, most then head sideways for miles out to sea.)

The Weald Basin has a short history of drilling for oil and gas. It all began by accident in the 1830s when two workmen were killed in a gas explosion in Hawkhurst in Sussex while drilling a water well. Around 250 hydrocarbon wells are recorded as having been drilled over the intervening years, most now abandoned. Gas was the early focus, until the 1980s, when high oil prices and new drilling brought some oil discoveries. In the 1990s and 2000s, an average of nine wells were being drilled per year. But many prospectors left the area, finding the wells too problematic and expensive and yields too small. Balcombe 1 well, drilled in the mid-1980s, was one such well, abandoned because oil flow was inadequate. Thirteen ‘conventional’ sites remain in production, around the fringes of the Weald, drilled into the Great Oolite.

In documentation accompanying the allocation of the 14th round of Petroleum Exploration and Development Licences (PEDLs), just before Christmas, 2015, all the PEDLs in the Weald were listed as ‘conventional’. This is consistent with the new definition of ‘conventional’ inserted into the government’s national planning guidance in 2014, where a ‘conventional’ source of hydrocarbons is defined as any limestone or sandstone formation. But this is incorrect and misleading, and will lead to decisions being made at local level in the mistaken belief that ‘tight’, ‘unconventional’ limestone-rich strata requiring acidising are ‘conventional’. If considered ‘conventional’, oil exploration in such ‘tight’ limestone-rich sources will raise less concern amongst public, planners, local politicians and the media.



Source: Professor David K Smythe

For these reasons, oil and gas companies are also keen on the word ‘conventional’, and not at all fond of the word ‘fracking’. Their applications mention acidising, but seemingly seek to blur the boundaries between acid wash, matrix acidising or acid fracking. (Acid fracking would probably no longer be called fracking under the government’s new water-based definition of fracking in the Infrastructure Act of 2015.) In the knowledge that fracking means fracturing – cracking open the rock under pressure – planners, councillors and members of the public need to ask about the intended pressure, and about the distance fractures and pathways are anticipated to penetrate into the rock. Councillors on the minerals planning committee in North Yorkshire proposed their own definition of fracking for their new Minerals Plan – pragmatically based on the rock being fractured.

Sulphurous, malodorous

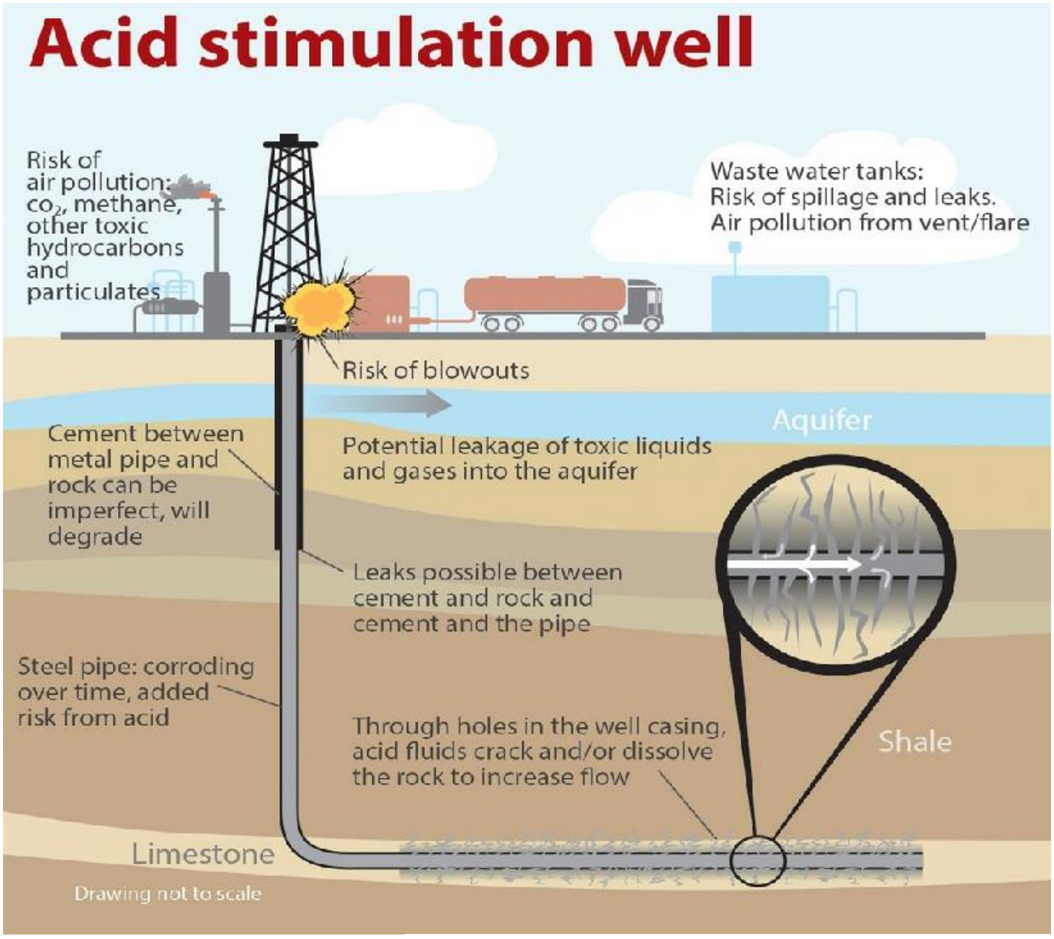
Oil from Kimmeridge formations (Kimmeridge clay = shale, Kimmeridge limestone = micrite) is ‘sour’ – smelling of sulphides, rotten eggs, boiled cabbage, hot water bottles… Heated to 200 °C, it gives off (lethal) hydrogen sulphide, which smells of rotten eggs. It proved too evil-smelling for use on Royal Navy vessels in the First World War, even when fuel was in short supply. The community around Horse Hill reported similar smells during recent drilling.

Regulation and monitoring

California has now regulated acidising, and Florida may soon follow. In Germany, where fracking is currently not allowed, extracting tight gas and oil is still permitted, although facing protest. English law and regulation has also concentrated on fracking alone. The Environment Agency, who admitted to holding virtually no historic data on acidised wells, is now collecting back data on a voluntary basis. The English regulators are understaffed, underfunded, facing further cuts, and grappling with Brexit; the Environment Agency is also intermittently immersed in floods. The regulators admit that they allow the industry to self-monitor. For the oil and gas companies, complying with regulations is expensive, possibly best avoided. And accidents happen. After the 2011 earthquakes at Preese Hall 1 shale gas well near Blackpool, Cuadrilla took six months to inform the government that the well had been damaged ('ovalised') over several hundred feet. This matters, because poor construction or damage to the well is the most likely cause of air, groundwater or formation contamination.

Conclusion

Acid stimulation poses a risk to our environment, health, quality of life and climate. Like fracking, it could cause oil and gas wells to proliferate in their thousands across our countryside. Yet no one is talking about it. It slips under the radar and avoids the regulation (weak as it is) and law that now surrounds shale gas.



Fracking Under The Radar - Weald Action Group Leaflet - 2017

Further reading

DIY acidising

- Do not try this at home, exciting as it sounds… http://petrowiki.org/Conducting_the_acidizing_procedure
- Very readable paper on acidising carbonate formations, from Schlumberger, Middle East and Asia Reservoir Review www.slb.com/~/media/Files/resources/mearr/num8/51_63.pdf
- http://gekengineering.com/Downloads/Free_Downloads/Acidizing.pdf
- The American Petroleum Institute on acidising www.api.org/~/media/files/oil-and-natural-gas/hydraulic-fracturing/acidizing-oil-natural-gas-briefing-paper-v2.pdf
- Swabbing (sometimes needed after acidising to make a well flow) www.tigergeneral.com/swabbing-well-explaining-process-simple-terms/

Hydrofluoric aid

- A Risk Too Great Hydrofluoric Acid in US Refineries, a union publication highlighting accidents, inadequate safety measures and poor preparedness for crisis management www.usw.org/workplaces/oil/A-Risk-Too-Great.pdf
- Harvard's Guidelines for the Safe Use of Hydrofluoric Acid http://chemistry.harvard.edu/files/chemistry/files/safe_use_of_hf_0.pdf

Blowouts

- Letter from a North Sea rig worker: https://peopleandnature.wordpress.com/2013/08/15/gas-blowout-on-totals-elgin-field-letter-from-a-north-sea-oil-worker-to-reclaim-the-power/
- German gas cloud: press release April 17th 2014 Frack Free Balcombe Residents Association: www.ndr.de/nachrichten/niedersachsen/lueneburg_heide_unterelbe/Saeureregen-auf-Soehlinger-Erdgasfeld%2cgiftwolke101.htm
- www.ndr.de/regional/niedersachsen/heide/giftwolke101.htmlhttp://www.radiobremen.de/gesellschaft/themen/regen170.html

Geology

- Dr Ian West of Southampton on Weald geology: www.southampton.ac.uk/~imw/Petroleum-Geology-Weald-Shale.htm

  Ernst & Young's report for UKOG, *Kimmeridge Limestone Oil - The UK Opportunity, Economic Impact Assessment*, published April 2016 www.ukogplc.com/ul/Kimmeridge%20Limestone%20Oil%20-%20The%20UK%20opportunity%20-%20Final%20Approved%20-%2015%20April%202016.pdf

Industrialisation

- Wells 'back to back' across the Weald, UKOG CEO Stephen Sanderson woos investors https://masterinvestor.co.uk/economics/shale-a-new-world-oil-order/
- See the video of his speech here: www.youtube.com/watch?v=5zBAD-EJHyk
- Analysis of potential oil industry across the Weald https://drillordrop.com/2016/04/18/weald-oil-production-could-generate-52bn-over-40-years-but-2400-wells-needed/
- Collected investor videos www.youtube.com/watch?v=rhsjlmXFI5Q

Waste water, flowback and produced water

- Engineer John Busby on the dilemma of treatment and disposal of water www.after-oil.co.uk/fracking_wastewater.htm
- Composition of flowback from acidised wells http://gekengineering.com/Downloads/Free_Downloads/Acid_Backflow.pdf

New technology

- SqueezeFrac': http://ener-pol.com/products/squeezefrac/
- Potential use of micro-organisms:
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.541.6940&rep=rep1&type=pdf Potential Uses of Micro-organisms in Petroleum Recovery Technology Rebecca S Bryant IIT Research Institute, National Institute for Petroleum and Energy Research P.O. Box 2128, Bartlesville, Oklahoma 74005

  'Microorganisms were considered to be detrimental to the petroleum industry in the past. It is now known that they can also be beneficial in terms of oil recovery. There are three ways in which micro-organisms may contribute to enhanced oil recovery (EOR): (a) microorganisms can produce biosurfactants and biopolymers on the surface; (b) microorganisms grow in reservoir rock pore throats produce gases, surfactants, and other chemicals to recover trapped oil in reservoirs; and (c) microorganisms can selectively plug high-permeability channels in reservoir rock so that the sweep efficiency of the recovery process can be increased. In this paper progress in enhanced oil recovery through the use of microorganisms, whether in situ or on the surface, is reviewed, and field tests of the in-situ process are reported.

California

- Khadeeja Abdullah's paper on *Acidizing Oil Wells, a Sister-Technology to Hydraulic Fracturing: Risks, Chemicals, and Regulations* http://escholarship.org/uc/item/6z9238sj#page-11

- Environmental lawyers in California on lack of information on the risks and implications of acidising: www.environmentaldefensecenter.org/wp-content/uploads/2016/08/OffshoreFrackingEAComments_SBCK_EDC.pdf
- Article on lack of oversight of hydrofluoric acid use in California: www.takepart.com/article/2013/09/02/acid-california-fracking-acidizing-monterey-shale