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Environmental Fracturing vs. Fracking

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While "fracking" is the subject of much contention in political and social arenas, environmental fracturing continues to make quiet headway.

Fracking" is a household word because of its controversial role in energy production, but for more than two decades the field of environmental fracturing has quietly contributed to the remediation of contaminated waste sites. The process and physics utilized during environmental fracturing are similar to those used when fracking for oil and gas recovery, however, significant differences exist with respect to scale, materials, and methodology. More importantly, environmental fractures are specifically designed and created for cleaning up contaminants, and therefore have avoided the environmental controversy and resulting headlines that surround the energy applications.

Fracturing traces its roots back to the 1940s when wildcatters (drillers of wildcat wells, which are exploration oil wells) developed hydraulic fracturing as a method for stimulating the production of oil wells that was safer and more effective than detonating nitroglycerin, which had been the standard practice since the 1860s. The fracking term was coined by the wildcatters. The basic technique of all fracturing involves injecting a fluid into a well until the pressure exceeds a critical value and the geological formation cracks. Solid granular materials, termed "proppants," are often mixed with the injected fluid to form a slurry that is injected into the growing fracture void. The fracture continues to propagate during injection, but it Stops and the walls of the fracture close when injection ceases. The result is a broad, thin layer that intersects the well and is propped open by solid granules. Oil and gas preferentially flow from the reservoir into these permeable layers and thereby increase well productivity. This aspect is what attracted the attention of oil and gas companies in the 1940s, and it is what motivates the applications in shale gas and other energy sectors today.

Application of fracturing technologies for contaminant remediation was developed during an EPA-sponsored research in the late 1980s to the mid 90s. Several companies who specialize in environmental fracturing started up during this period, and fracturing applications have since become an integral part of the contaminant remediation industry. These practitioners have honed the specialized methods for exploiting the chemical and biological characteristics of the proppants and forms of fractures.

The injection fluid used during environmental fracturing can be liquid or gas, providing some flexibility when it comes to design options. Inducing fractures by injecting gases is known as pneumatic fracturing. This approach may be preferred when the desired remedial strategy is sensitive to water or oxygen. For example, environmental fractures can be created by injecting nitrogen, which prevents the influx of oxygen into the subsurface. Creation of fractures with liquids (hydraulic fracturing) may be preferred when the remedial approach requires delivery of large masses of proppant material. This is because the concentration of solids that can be suspended in liquids is Greater than it is in gases. Guar gum gels are commonly used to create environmental fracturing slurries, which can have a solids content of up to 50 percent by volume.

Fracturing with proppant creates layers of solid material in the subsurface, and it is the geometry, or form, of these layers that largely control application strategies. Fracture plane orientation ranges from horizontal to vertical (Figure 1) . Fracture orientation can partially be influenced by well Preparation techniques and injection parameters; however, the major determining factor is the state of stress in the formation. Areas where the largest compressive stress is horizontal will favor horizontal fractures (typical of shallow depths), whereas vertical fractures are created where the largest compressive stress is vertical (typical of greater depths). Both of these orientations can be used for environmental applications.

Environmental applications

In general, environmental fracturing applications fall into two broad categories: enhanced well performance and passive treatments. Of the two, enhanced well performance applications (increasing rate per unit drawdown) are most similar to fracking in the gas and oil industries. Enhancing well performance in low permeability formations allows more efficient removal of contaminants for systems that involve pumping (pump and treat, soil vapor extraction, etc) or, conversely, accelerates the emplacement rates and expands the distribution of fluids for systems that involve injection (ISCO, enhanced bio, air sparging, etc). Fractures for passive treatment systems are created through borings or wells that are not intended for subsequent pumping or injection. Passive applications use the capabilities of environmental fracturing to deliver reactive solids, which are emplaced and left to degrade contaminants as part of the natural flow system

(Figure 1).

Low-cost granular solids, such as medium-grained, well-sorted, rounded quartz sand, are used to create hydraulic fractures for well enhancement. The fractional increase in well performance improves as formation permeability decreases, and environmental fracturing treatments are most effective when the permeability contrast between the environmentally fractured sand and surrounding soil/bedrock is at least two orders of magnitude. Well productivity increases can be significant in silty or clayey soil and in bedrock with extraction and injection rate increases that typically range from 10 to 50 times, with increases of multiple orders of magnitude in some cases. There are three primary mechanisms that lead to injection/ extraction rate increases after emplacement of sand-filled environmental fractures:

1. Improved Flow System – The extent and aperture of the fracture and the hydraulic conductivity of the proppant cause in-situ flux vectors to realign, head loss due to flow to be redistributed where less energy is consumed, and total flow to increase. Therefore, fractures support greater flow per unit of head or pressure, i. e. exhibit greater specific capacity.

2. Well Skin – Pumping energy is lost when flow must go through the low permeability material smeared as a skin during drilling a well. Hydraulic fractures can create permeable pathways through this low permeability skin.

3. Heterogeneities – High permeability features, such as naturally occurring fractures or sand beds, may occur in the vicinity of a well, but not actually intersect it. Hydraulic fractures can link these isolated features to the wellbore and improve recovery. Environmental fractures may also increase the permeability of pre-existing features, with dilation of natural bedrock fractures being the most commonly implemented example.

Passive applications typically involve creating treatment zones by filling fractures with reactive material, sealing the borehole, and then leaving the materials to do their job. The materials used for passive applications consist of chemically reactive solids, or materials that enhance biological activity, such as nutrients, buffers, and/or microbes (Figure 1). Some solids are sufficiently soluble and mobile to disperse from their parent fracture by advection or diffusion. For instance, fractures filled with potassium permanganate can be an in-situ source of a potent oxidant that is released to degrade contaminants for many years. This approach is particularly effective in fine-grained formations, where the flow is slow, but the contaminant mass is high enough for the region to act as a contaminant source.

Other applications require groundwater flow to transport the contaminants to the fracture where the remediation reactions take place. The ability to emplace materials such as granular zero valent iron (ZVI) make hydraulic fracturing an attractive alternative to trenching for creation of permeable reactive barriers. Fracturing processes are not depth limited, do not require heavy equipment, cause less surface disruption, do not produce large volumes of solid waste, and are less expensive than trenching.

Recent work has shown that the hydraulic conductivity of ZVI can be exploited in lower permeability formations to create reactive barriers oriented parallel to the groundwater flow. These permeable layers will capture flow over a significant cross section upstream from the fracture, according to recent simulations and theoretical analyses (Figure 2). The modeling shows that permeable horizontal fractures can capture flow over an elliptical, far-field cross section that is roughly 1.5 fracture diameters in width and 0.85 fracture diameters in height.

Environmental fracturing has been commercially available for nearly two decades and today there are at least six companies offering fracturing services to the environmental industry. When surveyed, companies currently offering environmental fracturing as a service, and the total number of sites where this technique has been used is in the range of 800 to 1,000, and the total number of fractures created ranges from 15,000 to 20,000 (Table 1). The versatility of environmental fracturing techniques has allowed application in nearly all types of geologic materials (Table 1), to enhance a wide variety of remedial approaches (Table 2), and to treat every major category of contaminants.

Environmental fracturing vs. shale gas ‘fracking’

Public concern over fracking is primarily because of potential environmental impacts, especially those that would affect drinking water sources or contribute to climate change. Potential contamination mechanisms that have received particular attention include fracture propagation into overlying materials (aquifers), well casing leaks into overlying materials, and failures of surface vessels and ponds that contain fracturing fluids. Secondary concerns pertain to water usage, heavy equipment and truck traffic in rural areas, as well as noise and aesthetics associated with fracking operations.

Environmental fracturing creates fractures by injecting fluid into the subsurface and those fractures are typically propped with granular solids, so in these respects the environmental techniques are similar to their energy counterparts. There are, however, some important differences setting environmental fracturing apart:

• Shale gas fracks are designed to recover gas from deep formations, whereas environmental fractures are designed to remediate contaminants in shallower formations. Every aspect of an environmental fracture is optimized to clean up contaminated ground.

• Environmental fractures are created with a few hundred gallons of liquid or several hundred cubic feet of gas, whereas fracking in shale gas may use millions of gallons of fluid (Figure 1). This is important because it is the volume of injected fluid that controls the distance the fracture will spread. The relatively small injected volume means that fractures used for remediation are simply too small to affect unexpected areas.

• The additives needed to suspend solids for environmental fracturing are innocuous. For example, dense slurries can be made with potable water, guar extract (used as texturizer in foods), borax (laundry additive, and a cellulose enzyme (used by brewers to clarify beer). These ingredients are also the primary materials used to create slurries for shale gas fracking, however, additional additives are required to maintain fluid rheology due to extreme temperature, chemical and pressure conditions within reservoir rock. These specialized additives are proprietary, and the primary source of environmental concern. These additives are simply are not required when creating environmental fractures.

• The pressure contained in a bicycle tire can be sufficient to create an environmental fracture. In contrast, inducing fractures in hydrocarbon reservoir bedrock requires thousands of psi. This is important because high pressures can potentially stress well casings and annular seals, which can result in leaks. The low pressure and small size of environmental fractures avoids detrimental effects on wells, such as leaks.

Conclusions

Environmental fractures are created by injecting gas (pneumatic fractures) or liquid (hydraulic fractures) and are typically filled with solid proppants. The technique has played an important role in remediating challenging sites in the United Stated, Canada and Europe for the past 20 years. It is used to increase the yields of wells, but it also is an important technique for delivering a wide range of reactive compounds that degrade contaminants in situ. While fracturing for shale gas makes headlines because of its potential to create environmental problems, environmental fracturing has enjoyed a long-term success because of its ability to solve them.

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