recent travel to countries where intestinal pathogens are rife. (Smoking or using marijuana, on the other hand, is no problem.) After filling out a questionnaire, about one in 10 applicants is asked to submit a sample, which is screened for more than 50 potential pathogens. OpenBiome has similarly strict criteria; only 2.8% of applicants make the cut. (OpenBiome pays its volunteers $40 per donation; Dutch law bans such payments.)

Regulatory agencies have yet to catch up. The U.S. Food and Drug Administration (FDA) has decided to treat fecal transplants as it would a biological drug, requiring doctors to file a so-called Investigational New Drug (IND) application when they want to administer an FMT. The agency has waived this requirement for *C. difficile*—but new draft guidelines, released in March, limit the exemption to hospitalmade preparations that use stool from a known donor.

Stool from banks would not fall under the exemption because FDA sees it as more risky. One reason is that relatively few, anonymous donors provide stool for many patients, meaning that any pathogens a donor harbors could spread widely. If the guidelines are adopted, U.S. hospitals might stop using stool banks, a prospect that has alarmed patients and FMT advocates. They worry that access to the procedure will become harder and dispute that hospitals' own products are safer.

In Europe, the regulatory future is unclear as well. No rules for FMTs exist at the E.U. level. Some countries, including the United Kingdom, France, and Germany, regulate FMTs as drugs, as FDA does; others have no specific regulation at all.

Meanwhile, several companies are developing new FMT products that could put the banks out of business. Rebiotix in Roseville, Minnesota, makes an FMT preparation using its own stool donors that comes with a guarantee that each suspension contains a minimum number of bacteria of sufficient diversity. Rebiotix finished a phase II trial for recurrent *C. difficile* in January, the results of which have yet to be published.

Other companies, such as Vedanta Biosciences in Cambridge, Massachusetts, hope to move away from stool altogether by growing specific bacterial strains in the lab. "It's sort of a natural progression, just like for aspirin, which started off with willow bark, and then we figured out that you could actually just synthesize the active component," says OpenBiome's co-founder and research director Mark Smith.

If these products win FDA's approval, Edelstein says, "clinicians will have to choose between a licensed biologic product or a stool bank. It might make it harder for [them] to work with us." Smith says that the higher prices that companies will need to charge to recoup their investments could prevent some patients from obtaining treatment; he says stool banks should remain a low-cost alternative.

Whatever the commercial future of FMTs, the stool banks say they'll have other work to do. OpenBiome may focus more on research, Edelstein says. Besides stool, OpenBiome provides guidance on experimental designs, safety protocols, and IND applications. The Leiden bank seeks to advance science as well. It just started a research collaboration with Vedanta Biosciences, and it plans to study whether fecal transplants should be given to *C. difficile* patients at an earlier stage. "Now, patients receive [an] FMT when they have tried all the other options," Kuijper says. "But more can easily benefit." ■

Tina Amirtha is a freelance writer in Leiden, the Netherlands.

The Netherlands Donor Feces Bank has accepted only five stool donors so far.

PHOTO: MICHEL GROEN

GEOCHEMISTRY

New solution to carbon pollution?

Instead of sending CO_2 up a smokestack, researchers in Iceland turn it into rock

By **Eli Kintisch**

Researchers working in Iceland say they have discovered a new way to trap the greenhouse gas carbon dioxide (CO_2) deep underground: by changing it into rock. Results published this week in *Science* (see p. 1312) show that injecting CO_2 into volcanic rocks triggers a reaction that rapidly forms new carbonate minerals—potentially locking up the gas forever. The technique has to clear some high hurdles to become commercially viable. But scientists say the project, dubbed CarbFix, offers a ray of hope for beleaguered efforts to fight climate change by capturing and storing CO_2 from power plants. "This is a great step forward," says Sally Benson of Stanford University in Palo Alto, California, a geologist unaffiliated with the project.

Dozens of pilot projects around the world have sought to test carbon capture and storage (CCS) as a way of curbing CO_2 emissions from power plants. Very few have been scaled up, owing to prohibitive costs, estimated at $50 to $100 per ton of CO_2 sequestered.

CCS also faces technical hurdles, and one of the largest is where to store the captured gas. Most researchers favor formations of sedimentary rock, often sandstone harboring briny groundwater or depleted oil wells, because industry has long experience in working with them. But scientists fear that fissures in the rock layers that cap the storage aquifers could let CO_2 leak back into the atmosphere.

So in 2006, Icelandic, U.S., and French scientists proposed a different approach: injecting CO_2 into underground layers of basalt, the dark igneous rock that underlies Earth's oceans and crops up in parts of continents as well. They knew that unlike sandstone, the basalt contains metals that react with CO_2, forming carbonate minerals such as calcite—a process known as carbonation. But they thought the process might take many years.

Carbon dioxide pumped into deep wells in Iceland underwent a surprising chemical transformation.

PHOTO: J. MATTER

To find out, they launched the CarbFix experiment 25 kilometers east of Reykjavik, intending to dose Iceland's abundant underground basalt with CO_2 that bubbles from cooling magma underground and is collected at a nearby geothermal power plant.

In 2012, the researchers injected 220 tons of CO_2—spiked with heavy carbon for monitoring—into layers of basalt between 400 and 800 meters below the surface. They also added extra water, which reacted with the gas to form a key driver of mineral reactions, carbonic acid. Then they monitored the pH, geochemistry, and other characteristics of the subsurface by taking samples from nearby wells.

What happened next startled the team. After about a year and a half, the pump inside a monitoring well kept breaking down. Frustrated, engineers hauled up the pump and found that it was coated with white and green scale. Tests identified it as calcite, bearing the heavy carbon tracer that marked it as a product of carbonation.

Measurements of dissolved carbon in the groundwater suggested that more than 95% of the injected carbon had already been converted into calcite and other minerals. "It was a huge surprise that the carbonation happened so fast," says Juerg Matter, a geologist with CarbFix at the University of Southampton in the United Kingdom. Laboratory tests by Matter's team and others, along with computer modeling, had previously suggested that carbonation in basalt would take at least a decade. (Sandstone aquifers are so unreactive that carbonation is thought to take centuries at conventional CCS sites.)

The speedy carbonation "means this method could be a viable way to store CO_2 underground—permanently, and without risk of leakage," Matter says. Unpublished data from a similar project in basalt near the Columbia River near Wallula, Washington, point to a similar conclusion. And there is no lack of basalt formations on land or offshore, which could make CCS possible for power plants "not near sedimentary rocks or depleted oil wells," Matter adds.

Bigger field tests are needed, says geologist Peter Kelemen of Columbia University, to confirm that such a high fraction of the injected carbon was mineralized. (Columbia is a CarbFix partner, but Kelemen is not on the project.) Scaled-up demonstrations could also make sure that the speed of the reaction won't turn into a drawback, Stanford's Benson says. If carbonation generates minerals that quickly plug the pores in the basalt, she worries, they could trap CO_2 near the injection site instead of letting it spread through the rock.

But even CarbFix's own scientists acknowledge that the biggest obstacle to CCS in basalt is financial: Power companies have little incentive to pursue it. "Without a price on carbon emissions, there's no business case," admits Matter, who hopes policymakers will create such an incentive. Otherwise, projects in basalt could suffer the same fate as the dozens of conventional CCS projects around the world that have failed to be commercialized. In the meantime, says Benson, the success in Iceland is a welcome development. "We could all use some positive news in this field," she says. ■

PSYCHOLOGY

Mechanical Turk upends social sciences

Growing pains arise for researchers using online platform

By **John Bohannon**

In May, 23,000 people voluntarily took part in thousands of social science experiments without ever visiting a lab. All they did was log on to Amazon Mechanical Turk (MTurk), an online crowdsourcing service run by the Seattle, Washington–based company better known for its massive internet-based retail business. Those research subjects completed 230,000 tasks on their computers in 3.3 million minutes—more than 6 years of effort in total.

The prodigious output demonstrates the popularity of an online platform that scientists had only begun to exploit 5 years ago (*Science*, 21 October 2011, p. 307). In 2011, according to Google Scholar, just 61 studies using MTurk were published; last year the number topped 1200. "This is a revolution in social and behavioral science," says psychologist Leib Litman of the Lander College for Men in New York City, who generated the May data from TurkPrime, a website that he created last year with computer scientist Jonathan Robinson, also at Lander, to facilitate MTurk studies. "Research is moving from the lab to the cloud."

Why bother with the cloud? A social sciences study with hundreds of live subjects normally requires weeks of work just to gather the data, not to mention finding people and signing them up. Last month's studies on MTurk—which include a test of the limits of people's generosity, a comparison of religiosity and humility, and a measurement of the psychological impact of graphic warnings on cigarette packages—took only days from start to finish.

But the platform's popularity has raised concerns, as researchers discussed at the Association for Psychological Science meeting in Chicago, Illinois, last month. Some worry that they are becoming too dependent on a commercial platform. "Academic research would be really screwed if Amazon decided to shut it down," says Todd Gureckis, a psychologist at New York University (NYU) in

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