Making bricks from regolith (because there's no Home Depot on Mars)

June 2 2016, by Joseph Mcclain

Robert Orwoll (left) raps a sample regolith-polymer brick with his knuckle as Richard Kiefer holds another sample. The two are working on a binder that will allow the first humans to make building material from the "soil" of Mars. Credit: Joseph McClain

Moses and Aaron, the Old Testament tells us, had to make bricks without straw before their people could leave Egypt and begin the journey to the Promised Land.

Bob and Dick have to figure out how to make bricks from regolith before their people can leave Earth and begin colonizing Mars.

Regolith is the Martian equivalent of what would be called dirt or soil on our planet. Bob and Dick are Robert Orwoll and Richard Kiefer, professors emeriti in William & Mary's Department of Chemistry. They are collaborating with a private firm, International Scientific Technologies, Inc. (IST) of Radford, Virginia. IST has received a Small Business Innovation Research (SBIR) award from NASA to help find ways to protect astronauts from space radiation.

Kiefer and Orwoll have a dual task. They are developing a procedure to bind Martian regolith with a polymer securely enough to serve as a building material, while acting as a radiation shield as well. There are many challenges to establishing a human beachhead on Mars, including finding a water source and dealing with the travel time necessary for making the trip. But radiation is one of the biggest challenges.

"Radiation is a very serious problem for NASA," Orwoll said. "You don't read about it much in the papers, but they've got a ways to go yet on solving the radiation problem before they can send anybody to Mars."

They make a good team. Orwoll is a polymer chemist, specializing in the structure and synthesis of the useful macromolecules. Kiefer is a nuclear chemist, studying the interactions of deep-space radiation with polymers and other materials.

"We have a background in doing this," Kiefer said. He and Orwoll worked on similar NASA projects involving lunar regolith and developing polymer radiation shielding.

"The most serious kind of radiation is called galactic cosmic radiation—GCR. It is particulate radiation, made up of just the nuclei of lots of elements," Orwoll said.

GCR particles are essentially cosmic shrapnel from supernova events.

Orwoll said that GCR particles are mostly hydrogen and helium nuclei, but can include nuclei of atoms all the way up to iron on the Periodic Table.

"It's a highly penetrating radiation, and very damaging, both to DNA and to electrical components on a space mission," Orwoll added.

Previous ventures into space have given scientists a good picture of the nature of how much GCR Martian astronauts can expect.

"When they sent up (Mars rover) Curiosity, they had radiation detectors on the thing," Kiefer explained. "They tracked the radiation on the full trip to Mars, and they confirmed that the dose was very high for humans."

Kiefer went on to say that the Red Planet doesn't offer the protections against cosmic radiation that have made life as we know it possible on Earth.

"Mars has a tenth of the atmosphere that we have. And it doesn't have magnetic fields," he explained. "So once you get to Mars, you're not shielded very much."

Consequently, the first humans to set foot on Mars will have to take at least some of their shielding with them. But most of the raw material will come from underfoot.

"I think people have contemplated for years using the dirt from Mars—the regolith," Orwoll said. "Think about hauling a bunch of construction stuff to Mars in a spacecraft! That just wouldn't be possible."

"Even Home Depot isn't there yet," Kiefer added.

"So it would be neat if a lot of the construction work could be done with material available on Mars," Orwoll said.

Kiefer and Orwoll have no Martian regolith to experiment with, but they do have a pretty good substitute. Curiosity, Pathfinder and other Mars missions have analyzed the chemical composition of regolith and scientists have found that there's regolith-like rock here on earth.

"It comes from a volcano in Hawaii. On the Big Island," Kiefer said. "A company in Wisconsin sells it. "

The rock, marketed as Martian Regolith Simulant, is quarried from the cinder cone of Pu'u Nene, a volcano between Mauna Loa and Mauna Kea. Scientists have been using the stuff to prepare for Mars since 1998. Kiefer and Orwoll have bags of it, in two different sizes, in their lab. Its chemical makeup is pretty similar to the regolith of Mars.

"There's a lot of silicate, like sand, in regolith. There's a lot of iron; that's why it's red," Kiefer said. "It's a combination of a lot of things, you know, just like dirt here on Earth. But regolith doesn't have any organic material. It would be more like you find in a desert."

Kiefer and Orwoll are trying to find the best polymer binder for humans to bring Mars. They experiment with different formulas, making regolith-simulant bricks in the lab. They've found kitchen-supply stores to be a good source of molds and so some of their rego-bricks resemble slightly overbaked loaves of banana bread.

The "best" polymer will be easily mixed, an effective binder and the most efficient by weight. Kiefer said they figure a good regolith brick should be no more than 10 percent binder, but of course they'd like to do better.

The final polymer binder would probably—but not necessarily—be in powder form. The collaborators have made progress in figuring out the most efficient type of polymers for shielding.

"We want polymers that have a lot of hydrogen in them," Kiefer said. "The reason is that hydrogen is the best shield for these galactic cosmic rays."

"On a per-gram basis," Orwoll added.

The collaborators pointed out that lead, a venerable and effective earthly radiation shield, is an obvious non-starter because of the weight. And surprisingly, hydrogen is more effective as a radiation shield than lead.

"You're better off with a pound of hydrogen than you are with a pound of lead," Orwoll said.

"The first time I heard that, I said 'Wait a minute,'" Kiefer said. "But a scientist from NASA showed me his calculations. He convinced me."

Hydrogen's effectiveness against cosmic radiation is a matter of defense by electron. Electrons carry a negative charge. Each hydrogen atom has only a single electron, but Kiefer pointed out that hydrogen, which occupies the leadoff spot in the Periodic Table, has one electron per one unit of mass. (Carbon, by comparison, is half as electron-rich, with six electrons per 12 units of mass.)

Kiefer explained that the particles of GCR are mostly naked protons, which carry a positive charge.

"So they interact with a negative electron by moving it aside," he said, "losing energy in the process."

Hydrogen has another virtue as a radiation shielding component. Kiefer continued to explain that some of the incoming GCR protons do their damage by shattering atoms at high energy. So, when a particle zooming in hits the nucleus of an atom of traditional shielding material, it flies apart, releasing considerable energy.

"And you end up with more radiation behind your shield than you had in front of it," he added. It's not a problem with hydrogen, whose one-proton nucleus won't split apart.

In fact, liquid hydrogen would make the very best cosmic radiation shield, Kiefer said, "but not very practical." Pure regolith adobe-style walls, with no polymer binder, would offer shielding as well, but would have to be a foot or so thick.

"But to do that, to make walls that thick, you are going to need some heavy equipment," Kiefer said. "So here's the trade-off: Do you take stuff to make bricks or do you take along a bulldozer?"

Topics like the bricks-or-bulldozer question come up often in conversations with Orwoll and Kiefer. Recondite details of hydrogen bonds in polymers and the interactions of cosmic rays are peppered with Martian speculations and what-ifs. Their discussion is reminiscent of the development section of a science fiction novel.

Among the ideas that get tossed around: The rego-bricks could be mass-produced at a landing site by robotic devices placed by an unmanned mission years before the first humans land. And it doesn't have to be bricks —regolith could be mixed with polymer bonder and extruded into logs. A bladder, protected by rego-brick outer walls, could be pressurized to Earth conditions, allowing Martian colonists to get inside and take off their space suits. A spacecraft designed to store their polymer binder in the fuselage walls of the cabin could provide radiation shielding for the trip.

Anything is possible, or at least a large number of things are, but first the chemists need to perfect their polymer binder. Both chemists are aware that their work has a high-tech, even a sci-fi, aspect. At the same time, they realize it's all about making bricks, something humans have been doing since before the time of Moses.

"If you get to an alien planet, low tech is all you're going to be able to do—at first," Kiefer said.

Provided by The College of William & Mary

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