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Lower-carbon concrete floors could pave the way to a health solution

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Suhi Hanif, a masters student in epidemiology and population health, investigated the transmission of diseases through soil flooring in homes in Bangladesh. Credit: Tarek Mahmud, 2023

Unlike dirt floors common in some rural parts of the world, concrete

floors are easily cleaned of disease-carrying pathogens—but they come at a high environmental cost. A lower-carbon flooring mix could provide a solution.

Simple concrete floors can easily be wiped clean of disease-carrying pathogens, unlike dirt floors common in some rural parts of the world. Yet that advantage comes with an outsized environmental impact due to heavy carbon emissions from concrete production.

Stanford epidemiologists and engineers are working together to develop a concrete flooring mix that would provide the same potential health benefits and structural support of traditional concrete but with a lower carbon footprint.

In addition to improving housing infrastructure, the mix could eventually be used to help lower emissions across the $700 billion global concrete construction industry.

Solutions from the ground up

Diarrheal diseases affect around 1.7 billion children each year. Jade Benjamin-Chung, an assistant professor of epidemiology and population health at the Stanford School of Medicine, worked with colleagues to analyze the impact of water, sanitation, and hygiene interventions on health outcomes in middle- and low-income Bangladeshi households in a trial conducted in 2012 and 2013.

They found that many common strategies used to protect children from disease, such as hand washing or maintaining latrines, were not as effective as expected, in part because they tend to be expensive and difficult for vulnerable communities to maintain over time.

Curious about what else might be contributing to the puzzling results,

Benjamin-Chung and her colleagues identified a potential culprit right beneath their feet.

Around 70% of rural homes in Bangladesh have soil-packed floors. As young children crawl, eat, and play on the floor, they often ingest trace amounts of human waste and microscopic soil-based parasites that transmit disease. Enter concrete floors: the home upgrade that could create a space that's easier to clean and reduce pathogen transmission.

"We started to get excited about concrete floors as a potential hygiene intervention, both because of this opportunity to interrupt exposure to soil for very young children and also because most of the people there aspire to have a finished floor," said Benjamin-Chung.

Benjamin-Chung mentioned her idea to Stephen Luby, a professor of infectious diseases and director of the Human and Planetary Health initiative at the Stanford Woods Institute for the Environment, who introduced Benjamin-Chung to Sarah Billington, an expert on concrete and building materials.

Over the years, Billington, a professor of civil and environmental engineering—a joint department in the Stanford Doerr School of Sustainability and School of Engineering—has researched different aspects of urban engineering, from earthquake-resistant design to environmentally friendly alternatives to cement.

When Billington heard the team's idea to broadly replace soil-packed floors with concrete to improve health outcomes, she worried that the approach could have unintended consequences for the climate.

How to make a lower-carbon concrete

Three main ingredients form all concrete blends: cement, water, and a

mixture of gravel, sand, or other aggregate material. Despite its versatility in the construction industry, concrete comes at a steep environmental cost; cement production alone accounts for 5–10% of all carbon emissions globally.

"So much of the work that I'm doing about well-being and urbanization is trying to ease up on the feeling of being in a concrete jungle," said Billington. "It was nice to see the positive benefits of concrete, but there are also a lot of negatives, so it's a really good challenge."

More than a billion people around the world live in homes with dirt floors. Billington was concerned that if researchers found that concrete floors improved child and maternal well-being, then governments and nonprofits might ramp up concrete (and by extension, carbon-intensive cement) production in a rapidly warming world.

Concerns about the climate impact of public health interventions are shared by many of the team's collaborators in Bangladesh, a low-lying nation particularly vulnerable to storms, sea-level rise, agricultural losses, and other impacts intensified by climate change.

Now, Benjamin-Chung and Billington are bringing other Stanford experts into the fold to understand why concrete is effective for reducing pathogen transmission and to design low-emission concrete alternatives that retain those helpful properties.

Alexandria Boehm, a professor of civil and environmental engineering and co-investigator on the project, brings experience studying microbes on engineered surfaces like concrete. Michael Lepech, a professor of civil and environmental engineering who focuses on concrete construction and structural integrity, is also a co-investigator.

They are working with community partners in Bangladesh like the

International Center for Diarrheal Disease Research, Bangladesh, known as icddr,b, to understand the unique context and needs of families who might upgrade soil-packed floors to concrete. Additionally, they want to develop a mix using ingredients that are readily available and affordable in countries like Bangladesh and could be easily installed with existing tools and infrastructure.

"We always talk about cracks in concrete, but now I'm like oh wait, I have to think about pathogens living in those cracks in the environments," Billington said. "It's a whole set of new, interesting curiosity points about the material."

One possible ingredient for a lower-emissions cement is recycled fly ash, a byproduct of burning coal. The heavy metals in fly ash are rendered inert when incorporated into cement, making it safe for household use. The resulting concrete mix is affordable, durable, produces fewer emissions, and makes use of hazardous material that would otherwise be sent to the landfill.

The experimental process begins in the Blume Earthquake Engineering Center. Jason Hernandez, a Ph.D. student in civil and environmental engineering in Lepech's lab, mixes and hardens concrete test tiles made with alternative "green" cement.

Hernandez then takes the tiles across campus to Boehm's environmental engineering lab, where he and his teammates inoculate the tiles with pathogens like E. coli to measure how well they survive on the surface with and without cleaning.

"It's uncommon for someone like me with a civil engineering background to take Professor Boehm's lab course in environmental health microbiology, let alone perform experiments in the environmental engineering lab," said Hernandez. "You could make the case that there

are at least four unique disciplines collaborating in this project: environmental engineering, civil engineering, epidemiology, and sustainability."

The team's initial findings suggest that E. coli and Ascaris suum, an intestinal worm like those often found in the soil floors of homes in the study site, have similar rates of survival on traditional cement mix slabs and "green" alternative fly ash slabs. This means that when installed in homes, the alternative cement mix could be just as effective as traditional concrete at reducing disease transmission.

Opportunity to make life better for moms

The team is deploying the new alternative concrete mix developed through the project as part of a field-based trial to rigorously evaluate the link between concrete floors and child and maternal health.

The team is working with the Village Education Research Center, a local NGO in Bangladesh, to install concrete floors in the homes of pregnant mothers in their second and third trimesters. Then, they will follow the child's health status for two years after birth, comparing outcomes for those born into homes with traditional soil-packed floors versus new concrete.

Beyond the physical health benefits, the team is also measuring the mental health benefits for mothers of using concrete floors in homes in the trial.

"Public health interventions for kids often focus on things that add to mom's workload, and I'm a mother of two young children myself," Benjamin-Chung said. "I'm in a very privileged setting, but I know how hard it is even in a very privileged setting to get work done when you have little kids running around."

Research suggests that concrete floors could reduce the time that mothers spend cleaning the home because they're easier to wipe down and sanitize. A 2009 study in Mexico showed that mothers had lower rates of depression and stress and higher self-reported satisfaction with quality of life after concrete floors had been installed.

"Stanford Medicine is just now starting to think about how we do medicine well without creating all this waste," said Benjamin-Chung. "This project could really be a model for how to do public health with sustainability baked in at the beginning."

Provided by Stanford University

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