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COVER STORY

A simple way to track your everyday exposure to chemicals

Silicone wristbands mimic how the body absorbs toxic compounds

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Credit: Will Ludwig/C&EN/Shutterstock

In brief

Simple, lightweight silicone wristbands are giving researchers a new window on people's environmental exposures to toxic organic chemicals. They sequester and concentrate organic compounds, with a chemical absorption profile similar to that of human cells. And unlike other devices for tracking chemical exposure, the wristbands are comfortable to wear. Read on to find out how scientists are using them to explore links between disease and exposure to pesticides, flame retardants, fragrances, and endocrine disruptors.

For one week, 92 preschool-aged children in Oregon sported colorful silicone wristbands provided by researchers from Oregon State University. The children's parents then returned the bands, which the researchers analyzed to determine whether the youngsters had been exposed to flame retardants. The scientists were surprised to find that the kids were exposed to many polybrominated diphenyl ethers (PBDEs), chemicals that are no longer produced in the U.S., as well as to organophosphate flame retardants, which are widely used as substitutes for PBDEs.

The results from that wristband study (*Environ. Res.* 2016, DOI: **10.1016/j.envres.2016.02.034**) remain qualitative—they tell parents whether their child has been exposed to a particular chemical but don't provide information regarding the amount of exposure. The researchers, led by environmental chemist **Kim Anderson**, are now working on ways to extract quantitative exposure data from the bands.

The work by Anderson's team is one of several projects evaluating the effectiveness of silicone wristbands to record exposure to organic chemicals in air, water, and personal care products. Interest in using the bands as personal exposure monitors has been growing since Anderson's team described the technology in a 2014 *Environmental Science & Technology* study (DOI: **10.1021/es405022f**). Increasing demand for the wristbands recently led Anderson to cofound MyExposome, a company that hopes to put the tool into the hands of the public.

A simple wearable

Silicone wristbands are easy to slip on, lightweight, and comfortable to wear compared with traditional personal air monitoring devices that rely on bulky air pumps, filters, and electronics. Study participants wear the bands for a specific amount of time—typically a day, a week, or a month. They keep the bands on at all times during the study—while sleeping, showering, jogging, swimming, eating, working, petting the dog, or reading their favorite magazine.

While they are being worn, the bands passively absorb a wide range of organic chemicals from the participants' surroundings, trapping them within the silicone polymer matrix. After participants return the bracelets, researchers extract chemicals

from them using various solvents or thermal desorption methods.



They identify the substances using analytical methods such as gas chromatography/mass spectrometry. Anderson's team has developed a GC/MS screening method that detects 1,400 organic chemicals from wristbands, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls, pesticides, flame retardants, fragrances, and endocrine-disrupting chemicals such as bisphenol A, phthalates, and nonylphenol. The number of chemicals that the method detects keeps growing, Anderson says.

The screening method provides qualitative information on whether the chemicals are present in the wristband. It does not provide information on the amount of each chemical. But Anderson and colleagues are working to change that. They have already developed quantitative methods for analyzing certain classes of chemicals, including PAHs, pesticides, and flame retardants, absorbed into the wristbands.

Anderson got interested in silicone wristbands after decades of work in the environmental field developing passive sampling technologies. Such technologies measure how much of an environmental pollutant is likely to end up in an organism, rather than how much of the substance is in water, sediment, or air. Merely determining the concentration of chemicals in the environment "is a poor surrogate for understanding the chemical load in organisms," she says.

While attending a football game years ago, Anderson noticed that several athletes and fans were wearing silicone wristbands. "I knew that was a material that I could adapt to be a passive sampler," she says.

Her research group had previously tried to make a passive sampler necklace. It was effective in some regards, but wasn't amenable to some job environments in which workers could be endangered by an item dangling around their necks. It also wasn't expected to be something men would be willing to wear, Anderson notes. So she and her colleagues began developing gender-neutral wristbands out of various carbon- and silicone-based polymers.

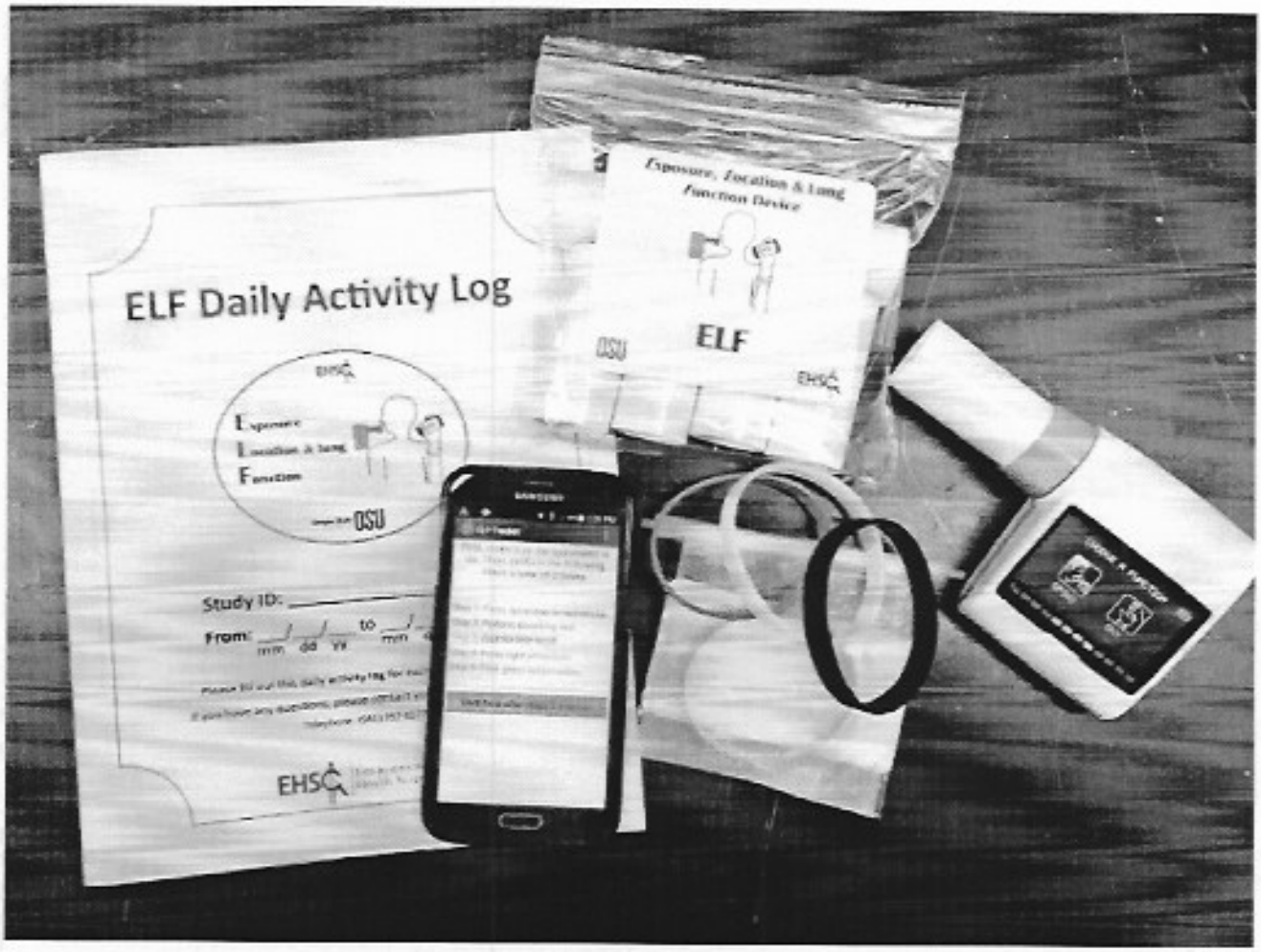
Silicone polymers are an attractive material for wristbands because they are more elastic than polymers made from carbon, Anderson says. Silicone polymers are also good mimics of

bioavailability because they contain long chainlike structures that form spaces similar in size—about 1 nm in diameter—to pores created by biological polymers in a human cell membrane, she says.

The wristbands are being promoted to the public by the Environmental Defense Fund (EDF), an environmental group that teamed up with MyExposome on a small project last year. EDF recruited 28 volunteers, mostly EDF staff and board members, to wear the bands for one week. Participants filled out a short activities survey. MyExposome analyzed their bands qualitatively for the suite of 1,400 chemicals.

EDF reported 57 chemicals were found in the bands, including PAHs, pesticides, plasticizers, phthalates, fragrances, preservatives, and flame retardants. Each band contained at least 10 and as many as 27 of the screened chemicals, with an average of 15.

The environmental group has since recruited a more geographically diverse group of volunteers, representing all 50 states and some international regions, to further test the wristbands. “We have now about 5,000 people who have signed up,” says Sarah Vogel, vice president of health programs at EDF.



Data from a portable spirometer (far right) that measures lung function is being integrated with location data from a smartphone's GPS and exposure data from a silicone wristband to explore whether chemical exposure affects lung function.

Credit: Holly Dixon/Oregon State U

Exposure matters

The bands have already made a difference for roofers in western Oregon, Anderson tells C&EN. A small group of the roofers wore the wristbands while working as part of a pilot project conducted by Anderson and colleagues at Oregon State to determine

whether the bands can be worn comfortably by workers who are physically active on the job.

When the researchers analyzed the chemicals in the bands, they discovered that roofers at a training location were exposed to higher levels of harmful PAHs than roofers at a job site. Even though it was just a small demonstration project, the data were compelling, Anderson says. The researchers communicated the information to the roofers' union, which prompted changes in how the workers set up tar kettles—a source of PAHs—and how the training site is ventilated.



The bands are also helping researchers examine whether there is a link between prenatal exposure to hazardous PAHs and asthma in children. Anderson is collaborating with Julie Herbstman, an epidemiologist at Columbia University, on a project with pregnant women in New York City.

"We put the wristbands on the women in their last trimester," Anderson says, and later follow their children's health for asthma and other adverse effects. The pregnant women also provide urine samples and wear conventional backpack polyurethane foam air samplers to monitor their exposure to PAHs.

The project just started last year, so it is too soon to tell if prenatal exposure to PAHs is associated with asthma in children. "You can't really diagnose asthma until children are two to three years old," Anderson notes. But the wristband results do seem to correlate well with PAH metabolites found in urine, Anderson says. The wristbands are more comfortable to wear, have lower cost, and are less of a burden to set up and operate than the backpacks.

In other work Anderson and colleagues are conducting, exposure data from silicone wristbands are integrated with location data from a smartphone's GPS and measurements of lung function taken with a pocket-sized spirometer. The studies aim to associate exposures to toxic PAHs with decreased lung function.

In one study, 10 adults with asthma in Eugene, Ore., each wore a wristband for one day and then wore a second band for one week. The smartphone pinged them three times a day as a reminder to take a lung function measurement with the spirometer, which was connected by Bluetooth to the phone. Afterward, researchers at Pacific Northwest National Laboratory downloaded the data and integrated them with chemical data from the wristbands.

Preliminary results suggest that lung function decreases on days associated with exposure to high levels of PAHs, Anderson says.

But in some cases, the effect lags. "What you are exposed to the day before affects your lung function the next day," she notes.

Flame retardants in children



Silicone wristbands are also helping researchers study the link between flame retardants found in electronics, furniture, and textiles, and adverse health effects, particularly in children. Heather M. Stapleton and colleagues at Duke University have been exploring such associations for more than a decade by measuring chemicals in the air and in house dust. They have also used hand wipes to examine hand-to-mouth exposure and dermal contact. When the researchers learned about the wristbands, they put them to the test to see how they compare with the hand wipes. The results were published last month in *Environmental Science & Technology* (2016, DOI: **10.1021/acs.est.6b00030**).

"We examined how the levels of organophosphate flame retardants on hand wipes and wristbands compared to urinary metabolites of those compounds," says Stephanie C. Hammel, a

graduate student in Stapleton's group at Duke. The study involved 40 participants who wore the wristbands for five consecutive days and collected urine samples on days one, three, and five. They used hand wipes on day five. Urine samples were pooled across the three days and analyzed for metabolites of four organophosphate flame retardants: tris (1,3-dichloroisopropyl) phosphate (TDCIPP), tris(1-chloro-2-propyl) phosphate (TCIPP), triphenyl phosphate (TPHP), and monosubstituted isopropylated triaryl phosphate (mono-ITP).

"For the compounds where we saw a significant correlation, the wristbands were more highly correlated to the urinary metabolites than the hand wipes," Hammel says. "We believe that the wristbands work better as a more time-integrated measure of exposure—or at least in this case a period of five days—whereas hand wipes might reflect more recent exposures," Stapleton adds.

How silicone wristbands act as personal exposure monitors

Silicone wristbands absorb organic chemicals from the environment. The bands can be worn at all times and continue to record a person's chemical exposure even as they sleep, shower, jog, swim, eat, work, pet a dog, or perform any other activity.



Silicone polymers mimic the way human cells absorb organic chemicals because they contain long chainlike structures that create channels similar in size (about 1 nm) to pores created by biological polymers in a human cell membrane. The wristbands take up polycyclic aromatic hydrocarbons, polychlorinated biphenyls, pesticides, flame retardants, fragrances, endocrine-disrupting chemicals, and many other persistent pollutants. The chemicals can be extracted from the bands and analyzed, providing a snapshot of an individual's chemical exposure over a particular time period.

