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0:00:05.7 Sarah Crespi: This is the Science podcast for November 19th, 2021. I'm Sarah Crespi. Each week, we share the most interesting news and research published in Science and the sister journals.

Could wildfires be destroying the ozone layer? Paul Voosen is a staff writer for Science. We talk about the evidence for wildfire smoke lofting itself high into the stratosphere and how the smoke might affect the ozone layer once it gets there.

Next, we talk ticks, the ones that bite, take blood, and can leave behind a nasty infection. Andaleeb Sajid is a Staff Scientist at the National Cancer Institute. We discuss her paper on using a vaccine to stop tick bites before they can transmit diseases to a host.

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0:00:58.1 SC: Now we have staff writer Paul Voosen. He wrote this week about smoke from forest fires reaching the stratosphere. Hi, Paul.

0:01:05.8 Paul Voosen: Hello.

0:01:06.5 SC: Your story opens with the Polarstern which is, I think, a research ship that has been featured on the podcast a number of times. We just keep going back to the Polarstern. And it's an icebreaker doing research up in the Arctic. And in your story, it's shooting a laser into the sky. What was it looking for?

0:01:24.4 PV: Yeah, the Polarstern was this... It got a lot of press coverage. It froze itself in a ice floe and drifted through the Arctic for nearly a couple of years ago. This laser it was shooting into the sky was initially designed to look for the interaction of small particles, called aerosols, and clouds. But they found something else entirely.

0:01:45.9 SC: They found particles in the stratosphere, likely from forest fires in Siberia. What's the evidence that that's the source for the particles?

0:01:55.0 PV: They had an advanced LIDAR there that can detect the fingerprint of smoke in particular. It gets pretty technical pretty quickly of just about reflection of light back versus what is absorbed at different channels. So that was their indication that it was smoke. There's still some dispute about this. Others say, "Oh, maybe it was volcanic." They are very convinced it was smoke. They've seen this signature in other places that were definitely smoke. Then they, using other space-borne LIDAR and other satellites too, tracked it backwards to the Siberian fires.

0:02:29.9 SC: Is this something that's been happening all along with big fires, the smoke getting up into the stratosphere? Or is it new?

0:02:36.7 PV: This is a very strange case because, typically, just in the past few years we've seen these big global warming-amplified wildfires. They've produced their big convective storms in Australia, British Columbia, that shoot into the atmosphere. These did not exist at Siberia. There was big fires, but there were not these big pyrocumulonimbus storms. So you would not expect these particles, this smoke, to get up to the stratosphere at all, let alone in large quantity like they saw. But there's a different dynamic that might exist for lifting these up.

0:03:11.4 SC: Yeah, how might this smoke get up there without a giant storm system to loft it that high into the stratosphere?

0:03:17.3 PV: There's this theory called, or this idea called self-lifting, where the smoke particles are so dark—they're so good at absorbing light and heat from the sun that, if you have a really kind of no winds, no weather of any kind really, just have this oppressive heat, they pick up that heat and rise because they are so hot that the air around them heats and they're buoyant, and then they just kinda keep shooting up. They can go up a kilometer a day and reach close to the stratosphere and then get whisked into it by winds.

0:03:48.3 SC: So the opposite of a storm. A complete lull.

0:03:51.0 PV: Yeah.

0:03:51.4 SC: What's gonna get this to happen. But we've been able to observe particles like this in the stratosphere for a long time with the space-based imagery. So is something different going on now?

0:04:02.9 PV: These sensors have existed since late '70s. And then people realized, "Oh, hey, wait, that's smoke." Late '90s, early 2000s. And so they were able to go back through the records. And talking to one researcher focused on using these historical measurements, they haven't seen this in any appreciable amounts 'til 2017. And now we see in 2017, 2020, maybe also with the Siberian fires.

0:04:27.4 SC: The appearance of these smoke particles, probably originating from Siberia, in the stratosphere overlapped with a dip in ozone levels. Why might the smoke have had an effect on ozone?

0:04:40.5 PV: This is the kind of most uncertain aspect of the work. Ozone chemistry is famously complicated. The work has not been done to kind of really chain this all together. There's a correlation that we saw this huge ozone dip at the same time as the smoke. There are a couple of different ways that this could deplete ozone, though. I mean, that makes sense to researchers who've studied this type of chemistry. These polar clouds form only in winter time. And these smoke particles could cause these clouds to form more droplets. And these little droplets allowed the chlorine that is in the stratosphere from CFCs, like pollution, to activate and eat ozone. Also the smoke droplets could get coatings that can eat through ozone, or they could enhance the polar vortex, which is this swirl of winds that causes cold temperatures. And the colder it gets, the more effective these chlorine chemical reactions get.

0:05:35.7 SC: What can be done to firm up some of these options? To figure out which is true or if any of them are happening?

0:05:41.5 PV: I mean, there's a lot of [chuckle] modeling. This is really an emerging kind of line of research, so it's just the full kind of chemical model that has to be worked through. But they also just need to know what those particles look like, what coatings they get. I don't know if that'll be aircraft campaigns or satellites or whatever to try and solve that, or lab measurements. There's just a whole raft of things 'cause just people didn't think this was a potential issue until five years ago.

0:06:09.7 SC: Right. Well, how does the depletion that was seen in concert with this forest fire smoke in the stratosphere, how does it compare with what we think of as the ozone hole that happened in the '80s and '90s?

0:06:22.2 PV: This is something that will kind of enhance natural processes. So the good news, the best news, is that you don't get ozone holes without that human-emitted chlorine and bromine in the stratosphere. So that's still gonna be there for decades, and it's gonna slowly go down. So this might be a short-term problem, if it is a problem. By short-term meaning decades long.

0:06:45.6 SC: Do we see a dip as drastic as we have in like the last century?

0:06:50.2 PV: The Antarctic, past couple years, saw big ozone holes. Nearly as bad as the '80s. It's getting better. The trend overall is still getting better, but with the Australian fires happening around that time, there's curiosity of is there a connection there, and then this Arctic dip didn't qualify as the ozone hole, but got very close. And I mean, that was just kind of very anomalous to see.

0:07:13.3 SC: Now, we've been focusing on the poles, the Australia fires possibly within Antarctic ozone depletion, and now maybe Siberia fires, linked with Arctic. But what about other parts of the world that have seen fires? Is it possible... This is again, taking kind of a couple steps beyond the state of the research it sounds like, but we're gonna see this in the mid-latitudes, around the equator, where if big enough fires happen we might get a depletion of ozone there.

0:07:38.5 PV: These fires are just gonna get worse. People don't think this is necessarily having a huge effect right now but if you see more and more of these fires that can reach the stratosphere, there's concerned and you need a lot more stuff. It's harder to reach the stratosphere in the mid latitudes, it's taller, and it's warmer, you just need more stuff to make bad things happen. But you don't want a lot of stuff going on in the stratosphere, right?

0:08:02.6 SC: Right.

0:08:02.9 PV: Right, that's not supposed to be a lot going on there. And if you're injecting these huge plumes, I mean, there's a lot of things to work out on, what's going to happen? This needs to be studied in climate models and everything like that.

0:08:14.9 SC: Do you know of any projects that are gonna look further into this, the relationship between wildfire smoke and the depletion of ozone?

0:08:21.9 PV: Yeah, there's NASA kind of high altitude campaigns, one will be going on this summer, more over the Great Plains, but if they get a big PYRO-CB convective plume if there are big wildfires, I think they'll try and zoom over in, sample that in, those have also been done in kind of recent past. I think they're still chewing through all that. It's always the dismal prospect of the scientists are hoping for big fires and big storms, great for science, but not so great for everyday life.

0:08:56.2 SC: Oh boy. Okay, thank you so much, Paul.

0:09:00.1 PV: You're welcome.

0:09:00.2 SC: Paul Voosen is a staff writer for Science, you can find a link to the story we discussed at Science.org/podcast. Stay tuned for my chat with Andaleeb Sajid about her Science Translational Medicine paper on an mRNA vaccine against tick saliva.

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0:09:23.4 SC: Lyme disease gets into people, from deer ticks that transmit a bacteria they're carrying into the person that they're biting, but the ticks have to stay attached for a long time for this to happen. Andaleeb Sajid is a staff scientist at the National Cancer Institute in Bethesda, Maryland. In this week's issue of Science Translational Medicine, her team wrote about a vaccine that makes ticks detach more quickly. Hi Andaleeb.

0:09:50.5 Andaleeb Sajid: Hi, Sarah.

0:09:51.8 SC: How common is Lyme disease in people?

0:09:55.4 AS: In North America and Europe, it's very common. Their CDC estimates are up to 400,000 a year cases.

0:10:04.1 SC: 400,000 or 40,000?

0:10:05.9 AS: 40,000 are reported, and CDC estimates can be even 10 times higher, so it can be 40,000-400,000, that's a big range I know, but there are so many cases which go unnoticed.

0:10:19.2 SC: How serious is it if you get a case of Lyme disease?

0:10:22.5 AS: A couple of friends of mine, they got the disease because of tick bite, and they were pretty healthy individuals, young individuals. And they had to take antibiotics for six months, and not only that, Lyme disease causes arthritis like symptoms, so you have pains in your joints, knees, ankles, so it's very difficult to even walk sometimes. In extreme cases it can cause carditis, which affects your heart, your neurological function. So I think it's pretty serious.

0:10:52.6 SC: Yeah. This is an mRNA vaccine, so that means that the mRNA in the vaccine is gonna code for certain proteins, the animal expresses those proteins, and then the immune system reacts and you get your antibodies. What proteins are being targeted with this mRNA vaccine?

0:11:12.0 AS: We used actually 19 proteins from the saliva of ticks.

0:11:17.0 SC: So, ticks spit?

0:11:18.2 AS: Yes, basically. So it would be surprising to some people, maybe the tick's saliva contains thousands of proteins which are important during the tick bite. So whenever you get a tick bite, it keeps biting over many days, but you don't feel a thing because those proteins suppress your feelings, suppress your immune response, any redness or anything. We chose 19 of those proteins, which represent different combinations. They are really antigenic, they suppress blood coagulation, they are immune suppressors.

0:11:55.6 SC: So you kind of choose from the array of functions and make sure that they are the kinds of proteins that stimulate a strong immune response?

0:12:02.8 AS: Yes.

0:12:04.1 SC: In your study, the work was actually done in guinea pigs. Why did you use this particular animal?

0:12:11.1 AS: It has been known that when ticks bite multiple times, animals generate so called tick immunity. After a second bite, third bite or fourth bite, there will be an immune response. But certain animals like mice, they don't generate tick immunity. Mice is the most common animal in animal models when these studies are started, but we could not use mice. Other animals like guinea pigs or rabbits even, they do generate tick immunity.

0:12:39.4 SC: Why do you think there is a difference between mice and guinea pigs in terms of their ability to generate tick resistance or immune response to tick saliva?

0:12:49.1 AS: It has been a long lasting question since many people are doing the research, the main thing that we could come across is mice are part of natural lifecycle of ticks. So if they generate immunity against ticks then tick won't survive for long, and they won't be able to replicate in nature.

0:13:06.9 SC: What you did in this study was you took your mRNA vaccine and you immunize guinea pigs and then you introduce them to ticks. In your experimental group, what happened when the guinea pigs had been immunized?

0:13:21.5 AS: There were two groups, one was control, which was immunized with the non-specific mRNA, then there was an experimental group. So when we do a tick challenge, we shave the backs of the guinea pigs because you cannot see how tick is biting because of the hair on the animals. We introduce around 25 ticks, and within few hours the ones which were immunized—our experimental group—they start turning red where the ticks were biting. You can easily see within less than 24 hours, we could see a decent redness, which is not seen in the control group even after four days, that redness really showed that there is a tick response immune response against ticks.

0:14:03.8 SC: So you start to see this redness at the tick bite in the immunized animals. What else happens?

0:14:09.5 AS: In the experimental group, these ticks were not feeding well and they start detaching by third day, which is very rare, it's called "tick detachment," "tick rejection." There was very strong tick immune response and tick rejection which led us that the vaccine is working pretty well.

0:14:26.3 SC: And what about the transmission of the bacteria that causes Lyme disease? If a tick had Lyme disease, and it bit an immunized guinea pig, is it going to transmit? Does it have time if it's detaching earlier than usual?

0:14:40.9 AS: There's a redness around 18 hours or 12 hours. And if you remove the tick right away, because if there is a tick bite and you see itching, you will immediately remove it, right? And we know that the causative agent of Lyme disease is called Borrelia burgdorferi, that pathogen takes at least 24-36 hours to transmit. Most of the guinea pigs, which were immunized with this vaccine, they did not get any disease.

0:15:08.1 SC: Did you see any infections?

0:15:09.8 AS: When we removed the tick at the redness, there was no infection. But if we let them bite till repletion, till they detach by themselves, half of the guinea pigs were infected, but half of them were not versus all of the infected ones in the control group.

0:15:25.0 SC: How did you give ticks the Lyme disease pathogen in this experiment?

0:15:30.1 AS: We maintain a colony of ticks. First, we infecting the mice and then ticks bite on them to get infected, and we then test the intensity of infection in like how much Borrelia is present in these ticks. So these ticks are almost 80-90% infected.

0:15:47.0 SC: Wow!

0:15:47.7 AS: Yeah, we make sure when we do a tick challenge in guinea pigs, they do transmit, but in nature it is very different, if you get a tick bite in nature, the chances are like 5-10% of the ticks are infected. So it is very skewed kind of experiment, that we make sure that we know the what if the vaccine is working or not.

0:16:10.2 SC: We mentioned before that this doesn't work in mice, in the natural world that they aren't able to become immune or tick resistant. What about if you use the vaccine on them, did that work?

0:16:23.3 AS: In this case, we could not see that redness, the detachment was not different from the control group. So that's how we knew that the vaccine is not really working that well in this group.

0:16:35.3 SC: So where do people fall in this spectrum? Are we more like a guinea pig or more like a mouse when it comes to our reaction to these kinds of deer ticks?

0:16:44.1 AS: I mean, we are far from both of them, but... [chuckle]

0:16:47.2 SC: So true. [chuckle]

0:16:48.6 AS: Yes, we need to do a lot of studies before we come down to humans. Right now the lab is working for rabbits. Rabbits are even higher than guinea pigs.

0:16:58.5 SC: Is there any evidence of the natural acquisition of tick resistance or tick immunity in people?

0:17:05.1 AS: It's not clear, really. We had this discussion before in our group that how will it react in humans, but most of the people if they are bitten by a tick multiple times in their lifetime, suppose you are a chronic hiker, you go every week, and you do have exposure to ticks every week or every month. So they do develop some redness. They know next time when there is a tick bite, but there is no documented proof, I would say.

0:17:34.1 SC: Oh, it does sound positive, though, that it might actually work for people too, but studies probably need to confirm that.

0:17:41.9 AS: Right.

0:17:42.3 SC: There is a vaccine against the bacteria that causes Lyme disease. The one that was approved is actually discontinued, but there are others now in clinical trials. Why focus on a vaccine against tick saliva rather than the pathogen itself, the bacteria?

0:18:00.1 AS: There have been many attempts before to make the vaccines against the pathogens, pathogen proteins, but here we are trying to target a broad community of pathogens, we know that they can transmit different kind of pathogens, like Babesia, Anaplasma, Borrelia, Powassan virus, they can transmit many kinds of agents. So a broad anti-tick vaccine strategy would be helpful.

0:18:28.6 SC: Is the timing going to work out the same way for these other pathogens that ticks may carry? If it's carrying the Lyme disease bacteria, it does take a while for it to come across. But what about the other pathogens?

0:18:41.1 AS: Yeah, some of the virus they transmit really fast within few hours, like less than five hours. So we don't know yet. If ticks are not feeding well, that is the idea. If they are not able to interact with host then they transmit the pathogen. There's a still possibility and there can always be optimizations in the vaccine.

0:19:01.2 SC: Thanks, Andaleeb.

0:19:02.2 AS: Thanks, Sarah. This was really nice talking to you.

0:19:05.0 SC: Andaleeb Sajid is a staff scientist at the National Cancer Institute in Bethesda, Maryland. The work we talked about was actually done while she was an associate research scientist at the Yale School of Medicine. You can find a link to the Science Translational Medicine article we discuss at science.org/podcast.

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