Setting the standard for cleaner skies podcast transcript

Introduction: [00:00:00] You are listening to a podcast from The University of Manchester.
In this podcast series, hear the University of Manchester's Dr Nic Gowland, interview some of our leading experts about how their research is helping to deliver the UN Sustainable Development Goals for global health, equality and sustainability.
Dr Gowland: [00:00:26] Today, I'm speaking to Dr Paul Williams, a Senior Research Fellow in the Centre for Atmospheric Sciences and the National Centre for Atmospheric Sciences, and an expert in aerosol measurement and aircraft emissions. Paul, welcome to the podcast.
Dr Paul Williams: [00:00:38] Thank you.
Dr Gowland: [00:00:39] So the simple question is how did you become an academic and work in atmospheric sciences? Was it always your dream to study this?
Dr Paul Williams: [00:00:44]. Um, no, it wasn't. Uh, when I was younger, I was very much, um... I liked being at school. I always enjoyed doing maths and science. Um, but I never ever had really a research, or even a career, path in front of me. Um, I remember when I was..., it was, probably about the fourth or fifth year of secondary school, thinking I'd like to go to university and do a degree in physics.
I really liked physics. I really like trying to understand how things work and why things work. Um, so I went to once university. Um, I did my degree. I did okay in my degree. So I thought I'll try and do my PhD. For my degree I did physics with electronics. So yeah. Then I was looking around. "I'll do a PhD." Um, and I thought, well, what PhD do I want to try? I thought, I'll try something different. So we are not done at all at undergraduate level. Uh, so I was listening to quite a few different areas. I listened to one from, uh, a professor in atmospheric science and he would be saying, "Oh, you'll be doing this on aerosols and be doing these measurements...", and I was listening and not paying too much attention until he said, "and you'll spend six weeks on Tenerife in your first year". And I thought, that's the PhD for me! Um, and then from there I enjoyed doing the research and, and then just carried on really.
Dr Gowland: And how was Tenerife?
Dr Paul Williams: Tenerife was amazing. I mean, I was, how old would I have been? 21, um, on really sunny island, six weeks work, and it was fantastic. It was, it was, it was great.
Dr Gowland: [00:02:06] The obvious question, from Tenerife to Manchester is, you know, how, how would you end up at Manchester? Was your degree at Manchester?
Dr Paul Williams: [00:02:11] It was. So, I'm a Mancunian born and bred. And at 18 years old, I was very shy and quite quiet. So, I was really looking at universities that were very close to home. And Manchester was top of my

choices. It wasn't Manchester, it was the old UMIST building then. Um, and I remember I picked UMIST and I got in and I would have been quite happy living at home, but effectively mum kicked me out of the house, in the nicest possible way. She had been to college herself, and she knew that a whole part of this, and also the growing up experience, was living out and becoming independent. So, she said: “No, you're going to live in halls”. Yeah. And it was, it was the best thing I did, doing that.

Dr Gowland: [00:02:45] So I'll let you jump in, give us the kind of background and the introduction to this case study and research then.

Dr Paul Williams: [00:02:49] Okay then. So, um, the aviation sector, a bit like the car sector, they, they regulate what comes out of their engines. Whenever you, whenever you have got an engine, you're going to produce some pollutants of some degree or another - things like CO_2. And along with the gases that we know, like CO_2 and NOx, we also produce little tiny particles as well. And now there has been an emission regulation in place since about the 1970s, based on something called smoke number, which is actually based on visibility. And when I give a talk on, on this sort of work, I show a nice picture from the seventies - this big engine aircraft taking off as black plumes of smoke are coming out the back. And it was… People didn't like seeing the plumes of smoke coming out the back. And this is what drove the regulation. It was an image thing. They didn't like the look of it. So, they introduced the smoke number and to force down the amount of, uh, soot coming out of the engines. So, as engines got cleaner and cleaner and cleaner, the soot went further away.

And we now, we don't see these big plumes coming out. And it got to the point where actually, smoke number now is not a good metric for what's going on in local air quality. Now, in tandem with that, we started to understand a lot more about the climate effects of CO_2, but also the health effects of these particles. And this led us to the idea that we need a new emission standard based on a metric that's more relevant to today's local air quality issues. And that is the mass, and the number, of these little sooty particles. And so that's where it came about. It was this driver to have a more relevant metric that impacts our lives.

Dr Gowland: [00:04:23] It wasn't soot particles that were causing the black clouds of smoke?

Dr Paul Williams: [00:04:26]. That's what you can see. That's what you can see. Most of that, some of that, is, there's potentially, if it was high NOx, you can sometimes see NOx if it's very, very high concentrated. But the majority of that was the soot coming out of the engine.

Dr Gowland: [00:04:37] So what you're saying is that the amount of soot had reduced so much that it wasn't visible anymore, but it was still present?

Dr Paul Williams: [00:04:43] And also on top of that, the methodology for determining this smoke number has a certain uncertainty. Whenever you make a measurement, there's always an uncertainty. The uncertainty and the method of making the smoke number measurements was actually bigger than the average smoke number.

There's also another uncertainty of the measurement which was much, much bigger than the actual smoke coming out at the end is. It was, it's just not fit for purpose for the modern day requirements of local air quality.
Dr Gowland: [00:05:09] Okay. So, before we move on to the, to your progress… Just then you mentioned NOx, can you just explain that, what NOx is for everyone?
Dr Paul Williams: [00:05:14] Uh, NOx is, uh, uh, nitrous oxide and, which are, again, they are a gas phase pollutant that you get in the combustion process, but that's not part of this regulation. It is purely the soot that's coming out.
Dr Gowland: [00:05:26] Okay. So, for the standard 1970s... So, then this is when it was your job, or your kind of project, (I know, you'll say it's not just you…, we'll go into that, the many, many collaborators), but it was this project's objective to update those regulations, yes?
Dr Paul Williams: [00:05:38] So the way it works with the regulation is that, uh, there's a, there's a body that regulates all aspects of aviation - and that's the International Civil Aviation Organisation (ICAO). So they're the upper body that regulates all, uh, aircraft, uh, safety and emissions, um, and different countries, in fact, nearly every country, will sign up to ICAO. So, if you sign up to the ICAO, uh, protocols, it means you all bound by their emissions. So, they determined, in about 2008, 2009, that this new metric was required, based on the number and mass, so they asked, uh, the society of automotive engineers, SAE, and they are a standard agency, so they write standards on how to measure, do things. And they tasked them with the, uh, project of coming up with this new methodology. So, within the SAE, there's a committee on aircraft emissions, of which I'm now a member, and they have set up, or they set up, um, then the goal to define this new measurement standard.
And then sort of trickling down from the SAE, the SAE has members from all over the world, and then the different funding bodies and regulators, such as the European Union Aviation Safety Agency, the European regulators, um, which did include the UK at the time. It doesn't now. They then started funding research into how to make these measurements and how we can standardise... In other words, how we can make this measurement protocol the same for everybody.
Dr Gowland: [00:07:02] You mentioned that the production of these particles can contribute to things like climate effects, but you also mentioned some health effects as well. Can you quickly just give us an overview of what sort of health effects might be?
Dr Paul Williams: [00:07:12] So this is, uh, this is still a very active area of research. Um, there's a lot of people trying to understand the, the health impacts of particulates, uh, on human beings. So, I think there's a, there's a, there's a… World Health Organisation report from 2016 that said, on average, about 4.2 million people died prematurely, uh, from air pollution particulates, and of that about 16,000 can be attributed to aviation. This is globally. Now, the only problem with that is that, well, the only concern about that is, is that it is based on a mass metric called PM 2.5. So, it's of the particulates that we've got a mass with a diameter, if you imagine the particle being a sphere that's smaller than two and a half microns. Now the problem is, aviation particularly produces very, very,

very, very, very small particles. So, you've got to have thousands, if not millions, of these tiny particles to have a significant number in the mass frame. So, what we're looking at now is, is, is mass… The right metric to assess health for, well, not just aviation, but all types of transport?

And actually this is where the research is going - is, is the number, because these very, very tiny particles are the ones that can get the deepest into the lungs. Basically, the smaller they are, the further we can breathe them into our bodies.

Dr Gowland: [00:08:28] So, what did this study set about to achieve them? What was the objective of this? Was it purely to set a new standard, or were there other things along the way?

Dr Paul Williams: [00:08:34] Okay, so first thing you've got to do is you've got to imagine - how am I going to measure behind a jet engine? So, a jet engine, when it's taking off, is shifting about one and a half tons per second. That's like a squash court's worth of air per second out the back. That's the total that's per second per engine on some of the big ones. And, you've got to imagine these things are incredibly hot. Several hundred degrees C. It's pumping out enough to shift a 40-tonne aircraft. So, you can't go up there with a little handheld probe and stand behind it and just look at a little monitor and say, yeah, I've got this many particles. You've got to think, how am I going to do this? So, it is an engineering challenge. So the project itself starts off by saying, well, what equipment can we use? First of all, we need to know what's going to be a good piece of kit to use. How are we going to couple that kit to a sampling system, and how are we going to standardise it?

So let's say Rolls-Royce, when they make measurements in the UK and report that to ICAO, cause that's what they have to do, how does that compare with a system which say, GE, which is an engine manufacturer in the States, make, and report to ICAO. So by standardising the system, we know we can compare these two numbers.

Once we've got this standard system in place, we make lots of measurements. We need to get an idea of what the numbers are. And then we can set a limit, or ICAO can set a limit. So this is a very lengthy process going from the fundamental of "what can we use?", to "what is the physical limit for emissions that we need to set?"

Dr Gowland: [00:09:59] There was a kind of a new thing, made to measure this, or, did it already exist?

Dr Paul Williams: [00:10:02] So this work involves a lot of collaborations. You, you mentioned this before, and one of those is the engine manufacturers and it's vitally important that they are involved in this. It costs millions and millions of pounds to make a, a measurement with one engine. And if you're not working with the engine manufacturers, Then, um, you just don't get access to this and this would never, ever happen. So, the engine manufacturers have, for many, many years, had to make emissions of the CO_2 and the NOx's and, uh, other gases coming out back. So they've got an existing infrastructure in place that sits behind an engine.

I've seen this at Rolls-Royce, and they've, they've got this fantastic sampling ring that sits behind their engines. If here at the end of day, it sits there and it's, it is literally tens of centimetres away. And all the engine manufacturers have a similar sort of, um, design as well. So, they've already got the infrastructure in place to take a sample. It's how we then basically process that, and then for these particle measurements.

Dr Gowland: [00:10:57] You mentioned production of these soot particles. How much of these particles is actually produced from these engines?

Dr Paul Williams: [00:10:59] So, let me start by asking you a question then. What do you think is the most, or the composition of the thing that comes out the back end of the engine? What does the engine mostly spit out?

Dr Gowland: I guess, smoke or carbon or something like that?

Dr Paul Williams: It's not, it's actually air. Most of what an engine actually produces is the air that it sucked into the front end, passes through the engine and comes out the other to give us the thrust. Actually, only 8.5% of, um, of what comes out of the exhaust, is actually a combustion product.

So, a lot of the things that we see here, soot particularly, that is a sign of incomplete combustion. So, in other words, we, haven't got a hundred percent efficient combustion system. So, it's producing a by-product. And soot is one of those byproducts. Now, if we're looking at this, in terms of that 8.5%, the majority of that is CO_2 and water vapor. Okay. And then the remainder of that is a few other gases. And in fact, less than about 0.00, or something, a really tiny amount, is actually soot. I think I saw some good at numbers, um, on a, on a, on a presentation. So if you've got a flight that's flying around and it's been there for about an hour, in that hour, it will produce about a hundred grams of soot.

So it doesn't sound very much, but you have to remember that there's, there's so much air flowing out. So even 0.00, or whatever, it is very small percentage, it's a very small percentage of a very high air flow. So, it does a slowly accumulate.

Dr Gowland: [00:12:30] So that's interesting, so even though you're focusing on that tiny part of the emissions, it's still incredibly key.

Dr Paul Williams: [00:12:34] Yes, they are. Yes, because we know these things do affect human health and do impact on local air quality. The way that these numbers are often reported is what is called emission indices. So, it's an amount per kilogram of fuel burnt. So, for an aircraft engine, in terms of mass, it might be half a milligram to 300 milligrams per kilogram of fuel burnt. And, in terms of a number, it is much, much higher as well. Something like two to the 13, that's two with 13 zeros on, or up to two to the 15, which is two with 15 zeros, per kilogram of fuel burn. But they burn so much fuel it actually then accumulates to be quite a lot.

Probably…, just putting that in context - even though those are…, those sound quite like big numbers, relative to something like the car industry, cars still produce a lot more in total because there are so many more cars. So, the amount that they're producing per kilogram of fuel might be a lot less, but there's just so many more.

And the road transport is still the bigger of the influences or things like soot compared to the aviation sector, for example,

Dr Gowland: [00:13:37] So you mentioned the technique here is to look at the number and the mass so that you don't miss… I suppose those tiny particles…How do you measure the number of something so small?
Dr Paul Williams: [00:13:45] We've got a lot of technology that allows us to count down to really, really small sizes. These things are called condensation particle counters and what they, what they did, with a very clever idea is, um, they make a small particle bigger. So, imagine the way the principal works is that they, they have a laser beam that comes in and a particle goes through a laser beam, as it goes through, it scatters the light and some way you got to detach. It just sees a light going boing, boing… and it counts scattering. It's easy to count scattering from a big particle. And so, what we do is we, we, we sample aerosol in, we make them bigger and then we can count them as they scatter. And that's how we do it. It's a very common technique. Uh, and we go down to very, very small sizes with this technique.
Dr Gowland: [00:14:27] So you've established this kind of measurement method. What's the next step of the study?
Dr Paul Williams: [00:14:32] So we established the method, uh, the measurement methodology. Uh, we started work on this, um, I think about 2008, 2009. We also started looking at the sampling as well. So, if we use different materials, a different lens, what are the impacts on that…, on our numbers? And then we understood all of this. And so, by about 2013, we'd established a protocol and a methodology for making these measurements.
Then moving forward from 2013, we then, uh, well, myself and University of Cardiff, uh, Manchester Metropolitan University, we started then to build, what's known as the, uh, European Union reference system. So, this is the system that is the gold standard for making these measurements. And, and then we also then got funding to start looking at, um, what are the uncertainties in this measurement? It's important to know uncertainties. If you've got really big uncertainties, it's very hard to know how to set limits. If, if the limits are within the uncertainty, there's no point in doing it. So, it's a very important part of it. Um, and then also then making measurements on aircraft engines so we can build up a database of emissions. So, that way then ICAO can ultimately set the limits.
Dr Gowland: [00:15:37] How are those limits defined - is this from your work or is this from health work or population work?
Dr Paul Williams: [00:15:39] So the, the European reference system is one of three systems in existence. Um, there's another one that's called the North American reference system. Um, and that one belongs to the FAA and it's operated by colleagues in Northern America. And there's the Swiss regulation system again, owned by, um, it's called FOCA, which is the, uh, Swiss aviation regulators. Um, um, we all work, we're all working on the same committees who sometimes work on the same project and whenever we can, we bring these reference systems together.
Um, and we've just taken measurement after measurement behind different engines. Now, the way that the, uh, engine manufacturers have to interact with this is… So, we've got this regulatory document that says, you must use this type of equipment. It must have this sort of sample line. It must have this flow rate.

And these temperatures. We prescribe exactly what they can and can't doand make it. Often they build their own system. They then have to show that their system is equivalent to one of the reference systems. So, they bring it along to a test, run it side-by-side, and we show the equivalent. And then, then as they have that, as they start populating a database that gives them the emission measurements, as that allows them to form, um, what is a reasonable standard to set for the limits.

The way it works to start with, is that it was an all past limit. So we found out what the current level is in production engines now. And we've set a limit on the mass emissions on that, or the mass concentration on that. And that's in place now. Um, we've also got the…, the manufacturers are required to report the number and mass emissions, which will then come into effect to have to be regulated from 2023 on new engine types, which will be a stringent limit to what the current mass measurement is now.

So, there's a mass measurement in place now, for in production engines, and there'll be a mass number standard in place by 2023 that's enforced from ‘23, which will be for new engines, which will be lower than the current mass standard, thereby, hopefully, cleaning up, uh, aviation emissions.

Dr Gowland: [00:17:40] Well, that's the ultimate goal of all this is to reduce the emissions - clean us, cleaner...

Dr Paul Williams: [00:17:44]

Yeah. So the European Union, um, a few years ago produced a document called ‘A Flight Plan in 2050’, where they set up some pretty ambitious goals for the aviation sector, looking to reduce CO_2 emissions by, um, about 75% NOx by, um, 65%, or something like that. So, they, they, they've got a very good road map of where they want to try and reduce emissions from, and I’m sure particulates will be involved in that going forward.

Dr Gowland: [00:18:12] How are things like these standards enforced? Obviously, I suppose they, they become a standard, but what's the kind of reality of that. If, uh, if an aircraft has an engine that emits above the standard, that is not allowed to fly - is that how it works?

Dr Paul Williams: [00:18:24] Pretty much.

So, it's as simple as that, so that when, when countries sign up to ICAO, um, they, they automatically have to meet the, the regulation. Like I say that any country can opt out of any part of it, so they don't have to do this, but, uh, most, most, most countries do. And, and it's then beholden on the aircraft engine manufacturers to meet that standard.

So, if they produce an engine, which currently let's say the mass is over the limit that they're allowed at the moment by that standard, it means that that engine cannot operate in an air space, which has signed up to the ICAO regulation.

Dr Gowland: So It’s very enforceable.

Dr Paul Williams: It’s very enforceable. They were - the local regulators, so ICAO’s not a regulator. It's, it's the agency that's setting the standards and overseeing, um, safety. Yeah so, FAA, for example, that they're the regulators. And they can say that engine can fly in our air spaces, or it cannot. It's as simple as that. And if they can't, and you could say, well, let's say the United States, for example, say, “we don't want to sign up to number”…, “we don’t trust the number regulation”, they're not, but let's just hypothetically say they did.

So gee…, you would go, “okay, fine”. “We can just produce particles, whatever we don't care.” We have to remember aircraft operate globally. They're not just going to fly around the US, so if they want to fly then from the US to Europe somewhere, and they haven't met the regulation, they wouldn't be allowed in European airspace.

So, even if one or two countries decide we don't want to assign it to ICAO, because it's a global industry, you're kind of forcing it anyway.

Dr Gowland: [00:19:51] Yeah, I suppose you're not going to get, you're not going to find the manufacturer who would therefore make engines above that?

Dr Paul Williams: [00:19:56] No, exactly. They suddenly limit their market because, because the aircraft operates all over the place.

There's going to be very few engines that are just going to fly about just in the States, or just in Europe, for example. So…

Dr Gowland: [00:20:07] Yeah, that makes sense. And I know you wanted to make a point of just how important these kinds of broad collaborations are, especially for such a global impact. Is this, you know, you, you see that as really important, these international collaborations?

Dr Paul Williams: [00:20:19] It is vital. Without them…

Um, like I mentioned, the, the aircraft industry, uh, they wanted, they want to keep informed. It would cost them so much money. If we, if they were to be told they have to meet a regulation, which they hadn't been involved in because it costs so much money from the safety and development point of view, to be able to make these measurements, um. And to have the regulators and the engine manufacturers and the scientists all around the table together.

There's always going to be compromises be made, um, when you're trying to define a regulation, but having them all work together, you get to the point when it comes to implementations of the standard that generally aircraft manufacturers are already meeting it. Because they're working towards that. They understand where it's going. They understand where the limits are going to be, kind of. And you have to remember, engine development takes years and years and years. So, a standard that comes in that's going to set new limits tomorrow would kill the airline industry if they hadn't been involved in it and started to make the improvements now to make the engines cleaner.

So just by being involved in the processes, they are cleaning themselves up ready so that they meet the standards coming in.

Dr Gowland: [00:21:23] So you've established this new, the new measurement that now is fit for purpose. The new regulation. Can this measurement that's been established or this measurement protocol, then just be applied to keep reducing, you know, to reduce it more. We can still use the same measurement or will we need, an update in, in 20 years of a new measurement technique, do you think?

Dr Paul Williams: [00:21:42] We’re looking at having to make improvements to the system now, so what we've found is that as this process has started, and as engines have developed, the technologies and the sampling systems that we defined are now becoming at the limit of detection of some of the equipment. So, whereas I mentioned with the smoke number measurement, the uncertainty was bigger than the actual average smoke number… We're getting to the point where we're getting onto the limit, certainly for the mass instruments, of where we can actually measure. So, we're going to have to either look to, uh, redesigning the system or just say, “engine’s are clean enough”.

The, with the sampling system that we've got, there are a lot of losses in other words, and this is always a problem when you do aerosol science, is it, if I, if I take a particle counter, and I want to measure what's outside my window, the best way for me to do that is put my counter outside the window.

But sometimes it's raining, sometimes it's wet. So I attach an inlet pipe to it. As soon as I attach an inlet pipe to it, I lose particles in that inlet system. And I have to correct for that loss. Now with the aircraft sampling system, you've got meters and meters of piping. It's very complicated. So there are a lot of losses.

So the number that we're measuring on the instruments isn't what's coming out of the back end of the engine. We have to calculate what that is, and that's part of the problem we're finding. Now, the system that we designed for modern engines is really at the limit. And part of that is because the engines are getting cleaner, but also because of the losses in the system.

Dr Gowland: [00:23:13] Aerospace in general is moving towards zero emissions, hydrogen fuel batteries... What are your views on that? Do you think that that's feasible? I know there are some people who think it may never be possible – a transatlantic flight with, with kind of zero emissions…What are your thoughts on that? Clearly, a good thing?

Dr Paul Williams: [00:23:26] So, with aircraft engines, looking at the current technologies, um, the engine manufacturers want to try and clean up their emissions, and they can do that by making the combustion more efficient, so, in other words, you get more bang for your buck with less coming out the backside. So that's one way of doing it. Another way that they're looking at doing it then - once you get to really good combustion is how do you reduce the amount of fuel going in? Because if you're burning less fuel, then you're going to be producing less emissions. Um, and the current technologies that are out there, the new ones are coming in, something called lean burns. Um, so GE have got one and Rolls-Royce are just about to start production of their lean burn engines and they see these as being able to reduce…, I think Rolls quotes about a 25% reduction in emissions. Now add on top of that, um, we have got these new fuels coming into line, sustainable aviation fuels, alternative fuels sometimes often made from crops seeds, and things like that. And there's evidence that they too can further reduce the emissions. So that's, you know, that there's ways that we've got now with the current technology that we can look to reduce the emissions. But going beyond that, there's only going to be so little fuel you can burn, or are so efficient than an engine can be.

So, you have to look at new technologies. Now there is talk about the battery, uh, uh, operated planes. Again, there's been a few test flights on these, um, and the other one, then the big one is going to be the sort of either hybrid electric engines or the hydrogen fuel ones. Um, I think we’re still a way, a long way off, but innovation and need will always drive these engineering challenges.

And I think Airbus came up with a release last year where they're talking about these new hydrogen engines, you can sort of Google it and you can find it. And they recognise there's a concept that they can look to do up to 2035, 2050, something like that... So it is, you know, I, at some point will be forced into that. I'm sure. So, um, a need will drive innovation.

Dr Gowland: [00:25:19] I suppose that kind of links on to my next part of this question, you know, As we move towards potentially zero emissions in aerospace, what, what do you move on to, when there are no longer emissions to measure, or will there be emissions in some sense?

Dr Paul Williams: [00:25:32] Well, I think if we're, if we're looking at 2035, 2050, then it's going to be pretty much getting towards the end of my career. So maybe, you know, the two will converge quite nicely on that one, no more particle emissions, I, I can retire at that point there. Um, but the group is I work in there. It's, it's very much about, uh, lots of different processes that produce aerosol, how they affect uh, climates and things like that. So my interests are, uh, not just in aircraft emissions. Um, it's aerosol particles generally. So there'll always be other things to look out for.

Dr Gowland: [00:26:03] Do you wanna just give a brief intro as to what, what are the things you're looking at currently and things you hope to look at in the future, future research areas?

Dr Paul Williams: [00:26:08] Yeah. So, um, one of the areas that we're looking at quite a lot within our group, um, is looking at things emissions are from, uh, domestic stove heaters, for example. So things like log burners and wood burners, they're actually producing a lot of particles now and that's becoming a noticeable problem. A lot of people use these for, um, more for cosmetic than for actual heating purposes as well. And we're seeing the levels of those increasing in cities. Um, the big problems those are causing places like Switzerland, where a lot of people actually still rely on them in the winter as their main source of heat. Um, we also look at the emissions generally from cities as a whole and the things that go on in there, and then how these things transport in the atmosphere, how they interact with clouds and how they're going to fall, uh, affects our climate and things like that.

Dr Gowland: [00:26:55] That's interesting. I mean, it's a bit of a tangent from this study, but what I do see a lot of these log burners, you know, a lot of my neighbours are getting them installed and things like that. Are they really quite harmful then to then, to the environment?

Dr Paul Williams: [00:27:06] I draw that I'll always be careful about talking about how harmful things are when it's not my area, but they do produce a lot of material.

Again, these have regulations on the emissions as well. So you have to go through an emissions standards and measurements to sort of regulate what comes out of that. But what we find with that is though, when there, the emissions on that one is you have a very well-defined procedure of how you load up your log burner with a certain type of wood, with a certain motion, a certain configuration, and what a lot of people do is you get any old stuff they can find in the backyard and palettes like that, ram it in there, and so so suddenly your real

world emissions can be significantly different to the regulatory emissions. And so it's trying to understand the real world impact Um, on these aerosols. I've been really lucky at what I've done in my career. I've made, uh, aerosol measurements on land, sea and air. So the UK’s got research aircraft as well, so I fly around in that and we fly around all over the world, making measurements of gases and aerosols and things like that. I've worked on ships, making measurements, going from Northern Germany all the way down to Cape Town, and work’s taken me on six or seven continents. And the only one I haven't been on is Antarctica.
And that's because I've got a family and I'd probably not have a family if I went there for a year and came back, sort of thing. So, you know, it's the, you know, there's pollution, there’s aerosol everywhere and I've, I've been incredibly lucky in what I've been doing, um, so far.

Dr Gowland: [00:28:27] Finally Paul, one of the things we're looking at as part of this podcast series is how the research is addressing some of the UN Sustainable Development Goals. Um, which goal, or goals, do you think this addresses?

Dr Paul Williams: [00:28:35] I think, I think it mostly taps into the responsible consumption and production, um, goal. Um, obviously this is a fossil fuel, uh, that we're burning to fly an aircraft there. Uh, anything that we can do to help reduce the consumption of the fossil fuels in the long-term is, is going to, is going to have a benefit.
So that the engine manufacturer, obviously like you mentioned, is to look into new technologies, uh, which I know, um, maybe not directly impacted by this emission standard, but as an engine gets cleaner, or as an engine technology changes, there are still going to have to meet these emissions standards so they can, if they're using an alternative fuel, for example, that was to produce more particulates, then they wouldn’t be able to fly. So you know, that this standard will ensure that as technologies and fuel types change, and they're trying to find something that's more sustainable. If it's not producing the same number of particles, then they won't be able to find that something that we need to make sure we keep an eye on, as things change with these, with the current tech, as it is.

Dr Gowland: [00:29:37] Well, Paul, it's been a pleasure speaking to you, I think this research over the years you've been doing is a fascinating piece of research. Congratulations to you and to the team. Um, and thanks very much for your time.

Dr Paul Williams: [00:29:48] No problem.

Ending: Visit our web pages to find out more about how we're delivering the UN Sustainable Development Goals and to keep up to date on our research and its impact across the globe. Go to manchester.ac.uk/research and subscribe to our mailing list. We're at the forefront in the search for solutions to some of the world's most pressing problems, seeking to be a global force for positive change.

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