Perfecting Motion® — Tribology and the Quest for Sustainability

Episode 7 – Green Chemistry
Contributors: Dr. Neil Canter, STLE Advisor, Technical Programs and Services, Dr. David Constable, Science Director, The American Chemical Society's Green Chemistry Institute®

Neil Canter:
We started to gain a better understanding of how the raw materials used in the manufacture of lubricants can be designed to be sustainable in our last episode when we discussed how waste plastic can be converted into fuels and lubricants. Waste plastics or polymers are produced through chemical manufacturing. With all the raw materials used to reduce lubricants to ride in chemical processing, we need to get a better understanding of how they can be designed to facilitate the production of more sustainable lubricants to help us move along in our continuing quest for perfecting motion. This leads us to the topic of green chemistry. Many of you, who are not chemists in all probability, consider the term green chemistry to be, well, contradictory. After all, how can chemistry, which has the connotation of high energy usage, high temperature processing, the potential generation of dark and malodorous chemicals, be green?

As a chemist, I've grown over the years to recognize that our standard of living would not be where it is without the discovery of chemical technologies that we need to carry on with our lives each and every day. Whether we need to drive to the grocery store, take an airplane from Point A to Point B, or in the case of a lubricant, be used to ensure that wind turbines can continue to generate power sustainably. To gain a better perspective on green chemistry and its impact on facilitating the development of raw materials to be used in lubricants, we are very fortunate to have Doctor David Constable, Science Director for the American Chemical Society's Green Chemistry Institute® with us.

David, thank you for joining us and welcome.

David Constable:
Thanks very much, Neil. Pleasure to be here.

Neil Canter:
Let me begin here by really some definitions. So why don't we start with the first base definition? What is green chemistry?

David Constable:
So green chemistry, as you know, has been variously defined by different groups of people. The way I look at it is really, it's a way of thinking about chemistry and how one practices chemistry, and one does that by three main ideas. One is to maximize resource efficiencies, so that is mass and energy inputs. The second, which is more less the way people classically look at green chemistry, which is the reduction

or elimination of toxic substances and pollution. And then the third bucket is to think about chemistry from a systems and lifecycle perspective.

Neil Canter:
We use the word sustainability a lot in this podcast. So, talk about this and what it is from your perspective and how the term sustainability relates to green chemistry.

David Constable:
So green chemistry is positioned at the center, think of a sphere—it is at the center. So that is the way you think about chemistry. Outside of that inner sphere of green and sustainable chemistry is lifecycle thinking. And outside of that is systems thinking, slash sustainability and what I mean by that is sustainability is historically or traditionally thought of as a triple bottom line approach, which means you need to simultaneously consider and optimize the interaction between economic issues, societal issues and environmental issues. So, life cycle is a tool that is used—we will talk more about this probably later—but it is a tool that allows you to think about what is green and sustainable, and then most of sustainability you have to understand is a systems level problem, okay, very large scale either earth systems or societal level or economic system issue that you need to think about. So, that is how I think about sustainability.

Neil Canter:
So why don't we build on your response and thank you for that and talk about life cycle analysis itself. What is it and how should it be used to determine if, let's say, a specific chemical substance or substances is green slash sustainable?

David Constable:
There are two ways to think about life cycle. One way is life cycle thinking and life cycle thinking is just okay I need to think about a product, for example, so I have a lubricant. I need to think about that lubricant from raw material extraction all the way through end-of-life considerations, right? And think about it from, okay, what are the environment, health and safety issues that attend each step of that path from raw material extraction. So, you said you talked about it from plastics—well you have to consider how plastics are made, right? You know you derive it from ethylene or propylene, for example, and you know you go through it. It has a useful life and then it gets pyrolyzed into a starting product for a lubricant or a fuel, right? That life cycle would look at every step of that process from raw material all the way through what happens to that lubricant when I'm done with it or to the car, you know the wheel bearings that are being lubricated, you know what happens to those things when they're done their useful life—so that's life cycle thinking. Life cycle inventory assessment is a very detailed, analytical process by which you look at inputs and outputs of every process and you do summing up or accumulative estimation of certain life cycle impact categories, so like greenhouse gases—that's the favorite for life cycle. So, people look at the cumulative life cycle CO_2 emissions associated with a lubricant from raw material extraction all the way through end-of-life considerations.

Neil Canter:
Thank you on that. So, let's bring in a few more terms I think certainly need to be discussed because people will think about them when they think about something that's green and think about sustainability and that is terms such as environmentally friendly, biodegradable, biodegradeability, and biobased. These have all been widely used. How do these factor in and relate to green chemistry and

sustainability? In other words, are they just marketing type terms or do they mean something a little bit more substantial?

David Constable:
They are more having to do with sustainability than green chemistry, so green chemistry really is focused on chemistry and the transformations that one has around chemistry, and it has a little bit to say about raw materials, but mainly, that's the province of green chemistry. So environmentally friendly to me is a greenwashing term. There isn't very little specificity to it. It's like environmentally friendly or environmentally preferred or whatever it happens to be. To me I run away from that kind of a term. I really do not like to use it. Biobased means that a certain percentage of the carbon that's in your lubricant, for example, comes from a biologically derived source, so it's biomass of some kind and it could be algae producing an oil, which is further changed into a lubricant or something like that, or it could be you can pyrolyze biomass and create a crude naphtha stream to build into a lubricant. So that's all that means is the percentage of carbon that came from a biobased source at some point in time. There's some really detailed work that's been done by companies like BASF, which had looked at a mass balance approach for getting into biobased and being very analytic about it.

I personally prefer degradeability because when you talk about the environment, you can find mechanisms to chemically degrade. So, for example, light can degrade things, air can degrade things and create a pathway to decompose that chemical and then that's different from biodegradeability, which has to do largely with living systems degrading your material. So, you know it goes into a composting situation or something like that where it's biodegradable.

Neil Canter:
Right, and I think one of the things it doesn't help here is there's inherent biodegradability, readily biodegradable, et cetera. I don't want to go into those terms. Let's move on and talk about the role, at least in green chemistry from the lubricant perspective, some of these certification programs have like the USDA (United States Department of Agriculture) Bio preferred program, or the EU (European Union) has an eco-label type program. What role do they play in defining substances that are green and sustainable in your view?

David Constable:
In my view, they are frameworks to evaluate the percentage of your product that comes from a biobased source. So that gets back into that discussion we just had about biobased and renewable, and they just, again, provide the framework for evaluating whether or not it comes from a biobased source. So, in terms of sustainability, the implicit assumption is that something that comes from a biologically derived source is more sustainable than something that comes from petroleum or fossil carbon.

Neil Canter:
Right, understood. So, let's go into some of this content that you've dealt with in your role with the American Chemical Society. You have talked about and done a lot with Sustainability Development Goals. Talk about what they are.

David Constable:
So, there are 17 Sustainable Development Goals that the UN promulgated in 2015 for completion by 2030. These goals are largely goals for nation states or government bodies to actually deliver on. But they are composed of a goal and a bunch of targets. What a lot of people don't know is you have these

17 goals which are like responsible consumption and production, for example, which the lubricants industry can talk about a lot of things that it can do under responsible consumption and production. There are a bunch of targets that are under those goals, and those targets are very specific actions, which, again, governments are supposed to be taking. So, it's in the targets that I think you'll see the most connections to your industry and how your industry will feed into that particular target. The other thing I will say is that many of these are cross related, so, in other words, you can talk about responsible consumption and production, but you could also, at the same time, look at connections with climate. You can talk about connections to land type issues and water type issues in terms of emissions and so forth. So, you have to appreciate that there's a lot of connectivity between the Sustainable Development Goals, but, ultimately, go for the targets and look at where the connections are.

Neil Canter:
So, one of the things that the American Chemical Society did was prioritized seven of these goals. So, talk about how that was done and what were the seven Sustainability Development Goals that the ACS prioritized?

David Constable:
Stepping back just a bit, the reason ACS came up with seven is because there are some that we're already doing, and we didn't feel it was necessary for us to call out. So, for example, quality education, gender equality and partnerships for the goals. Those are just three of several that we're doing and it's kind of written into what the ACS is about. The other seven are zero hunger; good health and well-being; clean water and sanitation; affordable and clean energy; industry, innovation and infrastructure, responsible consumption and production, and climate action. And the reason that these were chosen is in looking at the targets and thinking about what are the goals that chemists could connect to the most easily, these would have the biggest impact of the ones that were listed there. These seven goals are what ACS believed we're most easily connected to chemists and what they are doing. So, for example, in zero hunger, we have an Agrochemical Division, ARGO and Food Division, and so forth. In affordable and clean energy, we have several divisions that are devoted to thinking about energy and fuels and things like that. So that's really why those seven were chosen, as they were the ones that most closely aligned to readily identifiable things that the Society is doing.

Neil Canter:
Let's pick up on goal number 7, "*affordable and clean energy*" because frankly for us in the lubricant and tribology field that is a key thing for us, in terms of what we're trying to do to help facilitate those through the development and use of high-performance lubricants to help with things like wind turbines, which I mentioned in the introduction of the podcast, solar and other areas. Please talk about what's going on with affordable and clean energy from the ACS perspective and how that ties in with what's being done in the lubricant and tribology field.

David Constable:
Wow, there is so much that ACS is doing. Like I said, there are several divisions which program on a regular basis at national meetings. So, for example, energy and fuels, and so there's a whole series of things that are going to be related to that. Even in the ARGO Division, for example, they can talk about biobased materials that can go into creating oils and things like that. So, there's a whole series, again, of programming and activities that lead or contribute to thinking about affordable and clean energy.

Neil Canter:
How much of a role or tie-in has there been with lubricants and tribology, in terms of doing that because as I wrote in the question what might be the role of lubricants and tribology in helping to achieve sustainability goal number 7, it seems to be apparent that they can help facilitate affordable and clean energy. Has that moved into some of the areas where your divisions have been working to reach this goal?

David Constable:
To be honest, not so much. I mean the ACS does a lot of great things, but it has a very traditional approach to many things, so by that I mean there are certain areas of chemistry, say, materials where The Materials Research Society (MRS) has been created to think about the interface of materials chemistry. The same is true around lubricants where STLE was created to promote lubricants and the connections to lubricants and chemistry. So, the ACS is not as involved. That does not mean that there is nothing going on, but I don't know that there's a huge amount that goes on, in terms of lubricants.

Neil Canter:
Perhaps, this may be the beginning of what we're trying to do here—there could be a connection between STLE and ACS. This is why we're talking today and have you for this podcast, in terms of helping as we move along with the quest and goal to move forward with the sustainability and getting down the road where this could help, linking STLE and ACS to work together and helping to achieve that goal from both your end from the chemistry perspective and then from our end from the lubricant and tribology perspective.

David Constable:
No, absolutely I would agree 100 percent.

Neil Canter:
Let's finish up here by talking a little bit about your assessment on the future of green chemistry and sustainability. It's the second quarter of 2022, where are we and where is this headed from the green chemistry and sustainability standpoint?

David Constable:
There is still a tremendous amount of work that needs to be done. I talk about this all the time, in terms of if you look at the number of patents, for example, that are related to green and sustainable chemistry, it's really a vanishingly small number of patents. While patents may not be as good an indicator of translation of academic research into industry, it's a pretty good one. It's the best we've got I would say that some industries have picked up green and sustainable chemistry more than others, so the pharma industry by leaps and bounds is way further along the scale. The chemical industry not so much, and there's a lot more work that can be done in the chemical industry to make it greener and more sustainable—and that's worldwide. That's just not the US. There's just a tremendous amount if you look at, for example, most chemical production is shifted to China, and the reason a lot of it is shifted there is because they're willing to take the environmental hit, whereas the West is not. So, there's a tremendous opportunity in the reshoring of the chemical industry to the United States to actually do it differently and do it in a greener, more sustainable manner and that's really where I'm hoping things head.

Neil Canter:
Could you almost argue that the pandemic and supply chain crisis is facilitating that type of reshifting, not just for North America, but perhaps even for the EU as well?

David Constable:
Yes, absolutely! The other thing, frankly, that's shifting is the amount of hydraulic fracturing that's taking place in this country, and so you're seeing a renaissance in the petrochemical industry because of the amount of fossil carbon that's being created here. So, you are seeing lots more plastics manufacturing being reassured here for that. But again, that's not necessarily green, it's not necessarily sustainable, but that's why you're seeing a shift back.

Neil Canter:
The argument could be made a lot of it has been on the Gulf Coast. But there's at least one plant that has been publicized heavily and is getting ready to go commercial in the Mid-Atlantic Region of the US from that standpoint.

So, what steps should a lubricant manufacturer take if they're looking at their raw materials—and things are chaotic now as you know with the supply chain—but what steps should they look at if they want to be more sustainable? How should they look to determine if their raw materials are, in fact, formulating with because lubricants are formulated products much like cleaners and cosmetics, et cetera. How should they look to see what they can do to figure out if their products are, in fact, the raw materials used to make their products are green and sustainable?

David Constable:
So, for me one of the most exciting things is and this may be a few years down the Pike but is really around synthetic biology and tailored oils and that is that you use microorganisms to design the oil of your choosing. That's very doable. There have been companies that have come into existence have gone out of business because they're a little bit ahead of their time, but you can dial in properties very easily that way. And to me, that is the future without a question of making the industry more sustainable. It isn't, for example, you know going after monocultures like palm oil, and things like that. I don't think that's the right direction. I do sincerely believe that the future is in microorganisms and then tailoring them to make what you want by design.

Neil Canter:
Obviously, one of the challenges is to make that commercially viable so it can compete with the palm oils of the world**,** menthaoil, feedstocks and rapeseed type products that are in the EU, so all of those that are more readily available. Sunflowers is another one but understood.

So how quickly do you see the chemical industry moving into this way, moving its manufacturing products and taking these steps to become more green and sustainable? Obviously, there have been supply chain challenges and the pandemic that may be hindering some of this, but it's moving forward in that direction, David, I assume…I'm hopeful, at least. So how quickly is it moving and when are we going to see more progress, frankly?

David Constable:
One of the problems with all those sources you mentioned, you know like rapeseed or sunflower or whatever. My understanding is that the chemical industry requires specifications that don't change, and

one of the problems with natural products is getting that oil or whatever happens to be that feedstock to meet certain specifications consistently in significant quantities or the required quantities that make you a reliable supplier, right? And that still is something that is not worked out yet, in my opinion. So, I think that the industry wants it. There's a lot of demand on the part of customers who want greener, more sustainable products, but again they're not willing to pay a larger cost for that. So, it's got to be done in a way that is cost competitive to the incumbent, which is petrochemical-based feedstock and like you said it's evolving, it's coming, but there's still a lot of issues that need to be worked out in the supply chain.

Neil Canter:
So, I guess the message from the lubricant and tribology perspective is the chemical industry understands the challenges here and is trying to move in that direction. There are obstacles here, but it's moving in that direction towards sustainability, towards green and towards using these type of tailored technologies, which will get us to that goal—hopefully sooner than later.

David Constable:
Yeah, it will take time.

Neil Canter:
David, thank you. I appreciate your insights and comments as being very valuable for our podcast. So, thank you very much for your time.

David Constable:
Thank you, I appreciate the opportunity.

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CONTRIBUTORS

Dr. Neil Canter is an STLE Fellow and an STLE Certified Metalworking Fluids Specialist (CMFS)™, with more than 35 years of experience working in the lubricants industry. He received his doctorate in chemistry from the University of Michigan in 1983 and his bachelor's of science in chemistry from Brown University in 1978. Canter runs his own consulting company, Chemical Solutions, specializing in commercial development, marketing, product development and regulatory support for the lubricants industry. Canter is a member of STLE, the American Chemical Society (ACS), and the Society of Automotive Engineers (SAE). He is a contributing editor responsible for writing the monthly Tech Beat column in STLE's TLT magazine. He is also a member of STLE's Metalworking Fluid Education & Training Committee, STLE Education Committee, and the program chair for the STLE Philadelphia Section.

Canter recently assumed the position of STLE Advisor – Technical Programs and Services. Besides providing technical and commercial support, he is also the host of STLE's new podcast series: "Perfecting Motion: Tribology and the Quest for Sustainability."

David J.C. Constable is the Science Director of the American Chemical Society's Green Chemistry Institute®. In this role, he works to catalyze and enable the implementation of green chemistry and engineering throughout the global chemistry enterprise.

David has held a variety of industry roles in Energy, Environment, Safety and Health, focusing on influencing scientists, engineers and decision-makers responsible for chemical research, development and manufacturing in the Chemical, Pharmaceutical and Aerospace and Defense industries. He has developed a variety of programs, systems, tools, and methodologies that integrated sustainability, life cycle inventory assessment, green chemistry, and green technology activities into existing business processes.