Just Quick Screening Methods for Firearm Discharge Residues Transcript

Just Science theme [00:00:05] Now that this recording, RTI International Center of Forensic Science presents just science.

Introduction [00:00:24] Welcome to Just Science, a podcast for justice professionals and anyone interested in learning more about forensic science, innovative technology, current research and actionable strategies to improve the criminal justice system. Just science interviews. Dr. Tatiana Trejos, assistant professor of the Department of Forensic and Investigative Sciences at West Virginia University about the rapid detection of organic and inorganic gunshot residues. Speed and accuracy are vital when it comes to the analysis of gunshot residue. Dr. Trejos and her team are working on a comprehensive method for studying both organic and inorganic gunshot residue. Utilizing laser induced breakdown spectroscopy, this method focuses on providing accurate results, reducing wait time and preserving the evidence. Listen along as she discusses chemometrics and a novel tool for analyzing organic and inorganic gunshot residue. In this episode of Just Science, this season is funded by the National Institute of Justice's Forensic Technology Center of Excellence. Here is your host, Dr. Megan Grabenauer.

Megan Grabenauer [00:01:37] Hello and welcome to Just Science, I'm your host, Dr. Megan Grabenauer with the Forensic Technology Center of Excellence, which is a program of the National Institute of Justice. Today, our guest is Dr. Tatiana Trejos, host and assistant professor of the Department of Forensic and Investigative Sciences at West Virginia University. Tatiana, welcome to the podcast.

Tatiana Trejos [00:01:55] Thank you, Megan.

Megan Grabenauer [00:01:56] So looking at your bio, it says that you teach research design courses. I don't recall ever being offered anything along the lines of research design when I was in grad school was much more trial and error process. So what kind of topics do you cover in a course, like that?

Tatiana Trejos [00:02:11] So as you may know, West Virgina University is one of the only two universities in the United States that offer a Phd program in forensic science. So the program was developed to respond to the need for more specialized workforce. In one of the main objectives of the program is to prepare a new generation of forensic scientists that have better tools to provide solutions to forensic problems. So we went to prepare. Well rounded individuals will have more in-depth knowledge in the statistics. So we tried to incorporate a little bit more of that in our curriculum for our grad students. So the program usually offers at least three classes in statistics in the research design course that I teach quest custom-made for our doctoral students. So the course is then applied research and statistics based cause that introduce students through the analysis of simple and complex problems of forensic data and how they can design experiments and interpret their souls to make those experiments more cost effective.

Megan Grabenauer [00:03:15] So you go over things like appropriate sample size and sampling and that age and criteria, things like that.

Tatiana Trejos [00:03:23] That's correct, so the first portion of the class, the students, they were on models of conducting cost effective research designs. And so it started by identifying elderly when they are building hypotheses. What are the relevant questions to

answer? What are the variables and factors that can affect the outcomes of the research? What is, as you said, the proper sampling size, which is that one million dollar question that we have every time that we start doing research, how many samples is enough? Right.

Tatiana Trejos [00:03:54] And the answer it usually is that we always need more.

Megan Grabenauer [00:03:58] More than you can afford to do with your time or resources.

Tatiana Trejos [00:04:01] So that's one of the things that we all go over it with the students. So this is your problem and this is a variables. This is the question that you want to answer. How many samples do we need to get appropriate power tests without having to waste resources in and things like that? You will be surprised at how much time and effort and costs can be saved with proper experimental the science. So we tried to teach that to the students with real case examples. How is this different if you have to set up this same experiment for a research setting versus a case we're setting. And most importantly, how you can do it with a mindset that if you are doing our research, you will eventually be applicable to the crime scene or to the crime laboratory. So that's something that we try to teach in in the research design, how we can prevent it. Make sure the models that we're using fit for purpose, that they are statistically bonded, that we are using and strength of thinking that bonds all the possible factors that kind of like my outcomes.

Megan Grabenauer [00:05:06] So I know that a lot of your research up to this point has involved something that we call chemo metrics, which is a term that a lot of people may not be too familiar with. Would you mind going into a little bit of detail? Explain what chemo metrics is?

Tatiana Trejos [00:05:17] Yeah, absolutely. So, you know, metric is the use of mathematical and statistical methods to improve the understanding of chemical information. And that's what the chemo comes from or information, forensic data, for example. So I would say it's a fancy way of saying that we are playing statistics but we are aware that I'm not a statistician and so is application of math and facts to solve chemical problems.

Tatiana Trejos [00:05:45] Work with chemical data, forensic data.

Megan Grabenauer [00:05:48] So do you need a strong background then in math and statistics to go into this field?

Tatiana Trejos [00:05:52] Well, not really. I'm not a statitician and I think they have a lot of statistics classes in my career. So it was more like a self learning process. Also collaboration over the years as a practitioner and also in academia. Real statisticians that helped a lot in that process. So you have to give an example, a class that we were discussing earlier that having is that having statistics, we cover many other aspects like, for example, interpretation of evidence, including Bayesian methods. And that's not an area that I completely expert of. So what I'm normally doing those classes is that I invite guest speakers that patients and they graciously come and takk to students present their expertise in forensic science. For example, last year in the class, I had the opportunity to have i guess a speaker, James Grant from the University of Oakland, who is like an expert in statistics and forensic science as well. Application of statistics to forensic problems, including DNA and trace evidence. So I took the challenge to teach these classes and

incorporate statistics my research. But I'm not a statistician and that's something that we really want to change with our work programs.

Megan Grabenauer [00:07:07] That really sets a good role model, though, for you. You're not an expert in the field of statistics. You recognize that. So you bring in the expert to teach the students, make it think it really helps to kind of impress upon them. You don't have to do it all. You can collaborate and bring in people of different expertise when it's necessary.

Tatiana Trejos [00:07:27] Yeah, it's one of my mentors always told me one of the big lessons. They said, you don't need to know everything. You need to know what to collaborate with.

Megan Grabenauer [00:07:37] That's actually how I met you in the first place as we were starting to get in a gunshot residue research area. And I contacted Dr. Suzanne Bell and she said, well, you really should get in touch with this new up-and-coming professor at West Virginia University hired. And you guys could collaborate on some proposals and things together.

Tatiana Trejos [00:07:53] That's right.

Megan Grabenauer [00:07:55] But going back to the statistics question, I've noticed, too, that it's becoming more important in the area of forensics and some of the more recent in NIJ research and development solicitations that have come out, which are what you have to respond to if you want to get a research grant, there's a new requirement in there that you have to have a power analysis for your sample size.

Tatiana Trejos [00:08:12] That's absolutely true. And that's one of the things the very first thing that I teach now in these research class, how do you calculate and estimate a powered up analysis, how many different tools you can use to estimate it from experimental data or from literature as well? And how do you apply depending on what is are the hypothesis that you are formulating, what are the answers that you want to be looking at? What are the factors? What are the tests that you're going to be applying to test your hypothesis. So that's something that I actually enjoy teaching to the students because it's something that we didn't have to do five years ago when we were writing grants. Now we have to prove that the experiment of this line that we're proposing is going to have enough statistical power. So that brings an example how we have to it will and we have to use the statistics more and more often to prove that red-light really to our methods, the validation of our methods, the power of what we are proposing so we can really bring generalised conclusions rather than a conclusion that only applies to a particular study.

Megan Grabenauer [00:09:24] This week we are at the American Academy of Forensic Sciences annual meeting in Anaheim, California. And you presented at part of the NIJ Forensic R&D Symposium earlier in the week a presentation entitled Rapid Detection of Inorganic and Organic Firearm Discharge Residues by laser induced breakdown spectroscopy and electrochemical sensors. So, Tatianna, before we get into the details of your project, are there any other researchers who contributed that you'd like to acknowledge?

Tatiana Trejos [00:09:53] Thanks for asking that question. I'm glad you asked that. This is a very ambitious study and we could not have done it with many contributions and collaborators. So my undergrad students Emily Hailers, Zachary Andrews, Emily Halpern,

Arianna Veit and Kearney Dezel also grad students Carina Hargett, Kurnit Banderfile, Colby Ought, Bill Feeney, Pedro Calderon and post doc student Claudia Martinez Lopez. We have collaborators at the university level, so we have James Coran, which is a chair of the department of statistics in New Zealand. He is our statistician in the project. So he has been a fantastic resource for the interpretation aspect of this project. We also have another in-house is that the station that has been very helpful. Her name is Stacy Cald also WVU Department of Forensic investigative Science we have Dr. Kate Moritz, who has been a key collaborator in our project. We have at least the laboratory in our department. Also, my colleagues Suzanne Bell who has recently retired, but she has laid down a lot of the foundation on research and gunshot residue. From WVU we also have Paul Speaker from the Department of Finance, and he is the one that managed the Foresight Project so that when eventually we want to do plannings work, transition of the technology, he is going to be helping us with pilot laboratories to estimate the return of investment and see how much the adoption of this technology can really improve the efficiency at the laboratory and at the crime scene. We also have collaborated some international collaborators at the University of Costa Rica and from the industry who had a foothold labs in applying spectra from electrochemistry and lims respectively that have been very helpful as well to more work with us with how we can make this technology portable and also our contributors from the crime laboratories and practitioners we have Chip Pollak from the Sacramento Crime Laboratory.

Megan Grabenauer [00:12:05] I often hear both the terms firearm discharge residues and gunshot residue. Just let's let's get that out of the way right off the bat. Are those terms synonymous?

Tatiana Trejos [00:12:16] There is a synonyms I think that firearms discharge residue is used more like a more overarching general term. Gunshot residue has to make components. The inorganic gunshot residue is coming usually mostly from the primer and then the organic gunshot residue coming mostly from the propellant. So we normally refer to those two terms together as fire and pre charges.

Megan Grabenauer [00:12:43] That makes sense. I never knew that. But now I thought becoming clear. Can you briefly describe how firearm discharge residue or suspected residue has traditionally been analyzed? You're developing newer methods. So let's start with what crime labs have been using up to this point.

Tatiana Trejos [00:13:00] Gunshot residue is currently analyzed by standard methods using SEM EDS. This method has unique advantages that it allows to observe the typical sterile morphology of a gunshot residue particle. Often this particle, are s408 and are around 1 to 10 micro in diameter.

Tatiana Trejos [00:13:19] In this instrumentation has the capability to magnify many, many times to be able to look at that morphology of very small particles. In the instrumentation also has the capability to do elemental compensation in addition to the morphology. So standard ammunitions like heavy metals like lead barium and antimony are very relevant markers of GSR. And these method is used as a standard protocol in forensic laboratories practicioners are trained already in the operation and instrumentation. So its pretty much established technique all over the United States and abroad as well to do identification of gunshot residues.

Megan Grabenauer [00:14:00] What is driving you to look into newer methods? What are the current challenges or places where the standard methods fall short?

Tatiana Trejos [00:14:08] So regardless of its scientific validity, we still face several challenges in the field. One of them is that the current methods such as ACM ideas a very time consuming. Just to give an example, he can take up to eight hours. Do the analysis of one sample in a typical case will contain at least four samples per individual. If we are sampling the hands, we are going to be sampling right and left. But a palm plus a negative control just to make sure it was not cross-contamination. So if you start multiplying 8 hours per sample, that I usually fast is that absolutely fast and usually can take several days to do one case. So although the technique is great in the sense that as I mentioned, it can provide morphology, can provide elemental compensation is very robust. It is standardized, which is a great plots. The scientific reliability has been established. It is very time consuming. So that's when I'm thinking mutations that we have with this mentality. And therefore there is some need to find alternative analytical tools that can provide faster results without sacrificing the quality of the data. Another limitation of SEM EDS is that it can only analyze the inorganic constituants of the GSR, which are somehow prevalent in the environment. We can find led barium and antimony from many other sources. Soil mechanics tends to have high levels of these elements in their hands as well. So in order to decrease the potential for false positives, the community's looking at complementing the inorganic analysis with identification of organic constituents like big ones coming from the propellant or dicom powder in the stabilizers that are used also in those formulations. But at this moment, there are no standard consensus methods available for the analysis of the organic constituants. So that's what where our technology is coming. Tried to overcome some of those limitations. Can we do this in a faster way? Can we develop a method in which it can take only minutes instead of hours? And can we do detection both of inorganic and organic gunshot residue so that we can provide more confidence in our conclusions?

Megan Grabenauer [00:16:27] So in your presentation this week, another thing you mentioned is that the the standard ammunition is no longer standard. What is it about the ammunition that is is changing? What's different about it?

Tatiana Trejos [00:16:41] OK, so when I referred to standard ammunition I mean ammunition that contained components in the primer crop of the cartridge that typically are led barium and antimony. Those three elements are considered markers that are characteristic of inorganic controversy. And normally a standard ammunition will contain those three markers. And that will help us as some forensic examiners even find morphology and depressant on that particular part. The goal of these three markers that provides confidence that we are dealing with GSR over something else that looks vertical but may not be a GSR. However, due to environmental concerns, led three and toxic free ammunition is becoming more common. And that brings a series of challenges as other elements are used in the formulation that have led antimony, some of which are even more prevalent in the environment, in the background population and not as distinctive or what we call unique do. Gunshot residue formulations and therefore the need to expand our capabilities to attack all the markers like organic controversy's. So that's what I refer about there, not as a standard anymore, because we often now find a standard ammunition that is label as a standard that and thus contain the three elements we compliance standard ammunition that only contained led and antimony and not barium at all. Or we can find lead free ammunition that is sell as lead free or market as led free and contain still the heavy metals, including the led. So the formulations on changing a lot. And with that, we need to find a way to adapt to have better capabilities to detect those changes in the formulation and is still have the power of identify that as a bunch of restitute over something else that may have similar composition.

Megan Grabenauer [00:18:39] One of the technologies that you're looking into to fill this gap is laser induced breakdown spectroscopy. I am personally not too familiar with laser induced breakdowns spectroscopy. Can you go into a little more detail about what exactly that technology is?

[00:18:54] Laser induced break down spectroscopy is an analytical technique that can do direct analysis from solid liquids and gases. It is very versatile. So how it works is that we have a laser beam that is very, very fine in diameter. It usually can be from four microns in diameter to 100 micron in diameter. So you can find that laser of high energy direct link to your sample and that is going to create a temporal mycoplasma. So that mycoplasma basically a hot environment that contains excited species in those excited species very rapidly are going to go back to the ground level. When they do that, they meet a light that is characteristic of the elements that are present in the sample. So we have a spectra raps that have the capability to separate the different wavelengths of the elements that are present in the other section of many elements simultaneously. So in theory, we can half almost every element present in the periodic table that that that leaves in just few seconds. So it's a very versatile technique.

Megan Grabenauer [00:20:05] So what is the sensitivity of that? How many molecules of a certain element would need to be present for you to be able to pick it up using LIBS?

Tatiana Trejos [00:20:13] So the limits of perfection of LIBS depend on elements. There are elements that are more sensitive than others, but typically we can detect elements that are present in the low PPM range. Pretty low concentrations is fairly sensitive.

Megan Grabenauer [00:20:31] Then, along with LIBS, you're also looking at electrochemical methods. So what information are the electrochemical methods able to provide?

Tatiana Trejos [00:20:40] So the electrochemical methods work under another principle when they are looking inside the reaction redox reactions of the species under the stimulation of current or electricity. So what happens is that when we have molecules that are active to electrochemistry, we can detect organic and inorganic components at the same time. And so the advantages of these methods and very, very mature technique that has been used for over 60 years in the biomedical in the environmental industry, in the chemical industry. Just to give you an example, we use it every day. For example, the detection of glucose, those that pinched your your finger to get some detection of the blood and take what is your blood sugar level. Those some of those are based on electrochemical detection. So the same thing on the same principle applies to gushot residue. It has some very useful and disposable electrode, but it looks like a strip of only about 2 centimeters in length and that can be incorporated to a portable device that is not bigger than an iPhone. So we can use it to detect in seat to the presence of gunshot residue, all the species that are going to be active to electrochemical process. And when that happens, we can detect simultaneously in less than one or two minutes the elements that are present.

Tatiana Trejos [00:22:13] And in this case, for example, led barium antimony, plus the organic constituents that are present in the gunshot residue.

Megan Grabenauer [00:22:21] Both LIBS and the electrochemical analysis are much faster than the SEM approach?

Tatiana Trejos [00:22:30] A lot faster. So the LIBS can take seconds. So we normally do 25 replicates per sample instead of just doing one single analysis per sample and that takes only about a minute and a half. And then we can immediately after doing LIBS, we can do the electrochemistry experiment on the same exact sample and that usually takes less than three minutes. So overall we're talking that doing both LIBS and electrochemistry affecting organic and inorganic non-service residues is can take under 5 minutes per sample. So just to give you an idea of the timesaving some comparison to SEM EDS, we still using our project SEM EDS because that's the gold standard.

Tatiana Trejos [00:23:14] So when we are developing these in our large populations, we are doing analysis by electrochemistry and LIBS. And then on the same sample we do SEM EDS as our confirmation or cross validation of what we are obtaining by electrochemistry and LIBS. So last summer we had the opportunity to go and participate doing our research at the World Scout Jamboree in West Virginia. So we were able to collect samples from kids all over the world.

Tatiana Trejos [00:23:44] It was already a very exciting project because it wasn't first time that we were doing research at Jamboree Event. So we were able to meet kids from all over the world. It was amazing and we were able to collect samples from their hands right up right after they were shooting in the barrels.

Megan Grabenauer [00:24:06] OK, that makes more sense than why you thought the scouts might all have gunshot residue.

Tatiana Trejos [00:24:11] So we did the collection right after they were doing the shooting sports and we were able to collect thousands of samples in just two days. So it was a fantastic event. We also have another sampling location away from the shooting ranges, which we also collect background from the hands of individuals that has not fired a gun in the last 24 hours or so. So it was a fantastic opportunity for our group. And we came out with thousands of samples. We were able to analyze about eighteen hundred samples in one week by LIBS and electrochemistry. We are still under a hundred samples by SEM EDS. So that has being our challenge because we when you use SEM EDS as our cross validating method, but we cannot keep up with the speed. So we have to do it's a lengthy process and we have to do many less samples that what we can do with the technology that we applying.

Tatiana Trejos [00:25:13] And if you think about it like we were able to analyze the samples in less than a week, which is important, but at the same time we're able to detection very quickly. If we have to spend or wait months before we can finish up processing samples, we also increase the risk of losing the components on the sample as well. So that's another advantage of having faster method to process evidence.

Megan Grabenauer [00:25:40] Especially for the organic components, right? Some of those may be volatile. So if you have them sitting around for months, they may all volitalize and no longer be on the collection material.

Tatiana Trejos [00:25:50] You are correct.

Tatiana Trejos [00:25:52] So those are the ones that have been shown in different studies that are more prone to be loss over time. So the inorganic aspect of them like inorganic gunshot residue once you collect them and secure them in the carbon adhesive, they can

last for several months with no problem. The organic not so much. So you don't sample them and analyze them quickly. You have the risk to lose them very, very quickly.

Megan Grabenauer [00:26:25] What kind of instrumentation is required to perform this kind of analysis? You have to buy a special LIBS system. Or is it something that laboratories may already have in-house?

Tatiana Trejos [00:26:35] So we have several laboratories in the US that already have LIBS systems in their laboratory.

Tatiana Trejos [00:26:40] Of course they are not as spread out like SEM EDS. Every forensic laboratory that do firearm examination or gunshot residue will have an SEM in house because it is the workhorse instrument in the laboratories. So we cannot say the same thing with LIBS. Not every laboratory will have LIBS. However, one of the advantages of LIBS is that is more cost effective and much easier to maintain. So I will say that the cost of acquisition and maintenance is at least half of what an SEM EDS instrument cost. So in the long term, the return on investment will be very beneficial for the laboratories that want to complement that type of technology in the other hand electrochemistry is used universally in many, many areas aside from forensic science. But it hasn't found its application in forensic science, which is very surprising for me. There's a lot more now. A reason I will say in the last three, four years using electrochemistry for drug detection and for gunshot residues. But it's not fully incorporated in the forensic laboratories. However, the advantage of electrochemistry is that acknowledged is available out there. There thousands of vendors with different instrument configurations we're doing electrochemical detection for anything that is portable like in the size of an iPhone and something that can be the size of a laptop. And the technology is extremely cheap. You can have electrochemical detection with good performance with less than ten thousand dollars per unit. The electrodes that you use are disposable and they are less than one dollar per piece. So the adoption of these technologies is something that could be feasible and viable due to the cost of the instrumentation. And maintenance is very easy to train also personnel and something very easy to pick up and how to operate and how to understand that. So even though he's not broadly used in the forensic laboratories, I think has the characteristic features that will make the adoption of the technology easier in the future.

Megan Grabenauer [00:29:02] One of the other advantages I heard you talk about earlier this week is that both types of analysis, both the LIBS and electrochemistry can be done off of a single sample?

Tatiana Trejos [00:29:11] Correct.

Megan Grabenauer [00:29:12] Do you have to have any kind of specialized sampling material to make it a minimal LIBS analysis, something different than what you would do for SEM?

Tatiana Trejos [00:29:19] Something that we decided at the very, very beginning of our project is that we've wanted to use a new aerosol collection methods so we adapted our methods to the current sampling methods instead of the other way around. So we are using the same carbon stops that are used to collect residues from hands that are used by SEM EDS. But there is no need to change any of the protocols that law enforcement agencies have been used for years of years. So they everybody know how to use it, how to present samples. They're already standardized protocol for crime scene investigators,

law enforcement and for the laboratory personnel. So we didn't want to change that. So we adapt our methods to be able to operate with these type of carbon adhesives.

Megan Grabenauer [00:30:06] That's an excellent strategy. So nothing changes then for the frontline personnel who are at the crime scene doing the collection, although if this is to be implemented, all those changes are more on the back end. The laboratory analysis side.

Tatiana Trejos [00:30:19] Correct and we didn't want to lose all the knowledge that exists in terms of the ability of these samples. Once they collected, we know how they are stable, how you have to storage them. So we didn't want to provide any changes in the front line that would eventually we'll need also additional the studies to demonstrate that they weren't as well as the things that are used nowadays for collection of these type of evidence.

Megan Grabenauer [00:30:46] So when you've been talked about doing the SEM to verify your lives in electrochemistry analysis, are you also doing SEM on that same sample? All three techniques off the single sample?

Tatiana Trejos [00:30:58] Yes, we're using the three thing on a single sample. So we are using LIBS on electrochemistry as a faster screening tool, but since they are almost nondestructive to the sample, we leave I will say more than 80 percent of that carbon stuff unaltered during analysis. So we can do confirmation if we needed by SEM EDS on the same exact sample.

Megan Grabenauer [00:31:21] Is there any dependance on the order that you do the analysis? Can you start with that SEM and then do LIBS and electrochemistry or could you start electrochemistry and then do SEM and then LIBS?

Tatiana Trejos [00:31:31] So we have tried different sequences. So we have tried LIBS and electrochemistry or electrochemistry and LIBS and we're able to get very similar performances. It really doesn't matter much. We haven't done however SEM EDS first or two reasons first, because what we want to propose is to use these as a frontline. The first faster screening that we have to do if we find positive results and we need to confirm, then you go to SEM EDS.

Tatiana Trejos [00:32:01] Otherwise you can kind of triage that analysis on that case so that you avoid to use more expensive and time consuming methods for confirmation. So we haven't done SEM first for that reason, but then there is another practical aspect that we haven't tested, but that's our hypothesis and is that when you use SEM EDS, you have to play the sample under high vacuum and we may have the risk of losing our volatile compounds when we put this sample on the SEM. This is our hypothesis, we haven't tested, but it will make sense that if we put the sample on SEM, you run the risk of losing your organic components. So you want to do that only at the last resource if you want to confirm the results for any reason in that particular case.

Megan Grabenauer [00:32:53] So that's interesting to hear you say that you would still use SEM as a confirmation. Do you think that the LIBS electrochemical approach are robust enough to act as a confirmation themselves eventually, or do you think the same will always be a part of the picture?

Tatiana Trejos [00:33:07] So I think that has to be evaluated in my case to case basis. What we kind of envision is to have electrochemistry and LIBS as confirmatory as SEM EDS in many cases. Right. So we have been doing population studies and so far we have been able to get accuracy's ranging from over ninety five percent when we combine the inorganic and organic gunshot residues. So so far there is good evidence that they can be as confirmatory because you are not only detecting inorganic, but also organic gunshot residues. And although we are not being able to look at the morphology of the particle like in SEM, we develop them LIBS methods in such a way that we also gain certain level of spatial information. So even though we can not see the particle or guarantee that we obtain a signal from a single particle, we reduce the sampling area to only a hundred micro and we can know exactly from what area in this thought we obtain the simultanous detection of the inorganic gunshot residues.

Megan Grabenauer [00:34:18] Can you talk a little bit more about what steps you've taken to validate these methodologies?

Tatiana Trejos [00:34:23] So there are different steps of the validation.

Tatiana Trejos [00:34:26] The first one has to do with the analytical validation of the method. So we look at figures of merit like limits of detection, selectivity. Are there any other species that produce an interference with the elements that we are detecting or the organic species that we are detecting. We look at the qualitative and quantitative aspects, including limits of detection, limit of quantitation, linearity of the method, precision of the measurements as well. And then once we look at those figures of merit and we have an idea of the ground on how much we can detect and which what level of selectivity and sensitivity we can take this species, then we move to what we call a validation using population studies. So what we do is that we analyze with doing on some real samples. So shooters or non shooters. And from those ones, we know the ground truth, right? So we collect samples from the hands of the shooters and we are expecting on those samples to be able to detect the GSI. And then we have a background population of known shooters and we expect to not find interference. It's something that will mimic that composition of GSI. So we do the analysis of large populations. We are proposing around a thousand samples in our study in which we can evaluate how many times from a sample that has collected being collected from a shooter. We get a positive result so we can claim the true positive rate in those times that we didn't get a positive result from a sample that we knew that came from a shooter then we can calculate what is I would false negative rate, how many times we don't get those GSR profiles when we know that the person has fired a gun. And likewise from the background population we can testing estimate how many times we correctly not indentified any GSR in how many instances we have a false positive. So in all these cases we want to evaluate like low rates of false. Low rates of false negatives, and with those two, together we can calculate the oral accuracy of the methods. So that's a way in which we validate how many times we can correctly associate the presence of GSR with a firing event. How many how, how common is to find the inorganic and organic residues in the regular population?

Megan Grabenauer [00:36:59] So how is the combination of LIBS and electrochemistry doing? How is it fair in your validation studies?

Tatiana Trejos [00:37:05] They have been most relatively very powerful and complementary so just to give you an idea, there are elements that are detected in LIBS that are very good emitters, very sensitive. like barium, for example, and led in some elements that are not as good in electrochemistry. For example, barium is great for LIBS,

but we cannot see it in electrochemistry because it has a very high potential of oxidation. So we cannot see it, but is our best emitter in LIBS then electrochemistry is very sensitive for that and for antimony too. So they compliment each other. LIbS has the capability of detecting almost every element in the periodic table. So it is not only limited to the standard ammunition. So we can detect many other elements that are present in free or nontoxic combinations. In electrochemistry in addition to that, kind of look at the organic constituents so we can see to 2 4 DMT, DPA, it feels Senthorun like those compounds that are important markers on GSI. So when we combine those two together, we get a lot more confidence in the result because the chances of getting both the inorganic and organic markers in a sample that originate from GSR are going to be less likely. If we don't evaluate only inorganic and organic get set separately and something that we have also seen that help a lot with accuracy is that is so far in what we have observe is less common to find organic gunshot residues on the hands of the regular population. So you also decrease when you combine the organic and inorganic that create this chances of obtaining false positives as well. So he helps in both directions when we combine both and reduces the false negatives and also false positives. So when they are together, we have very good accuracies.

Megan Grabenauer [00:39:09] Do you think the science will ever advance the point of being able to reliably tell you who fired the gun to distinguish the shooter from the non shooter that maybe shook the hand of a shooter?

Tatiana Trejos [00:39:22] That is a difficult question. And so I think with definitely that knowledge can help us to get a better answer, a better idea. But we always have the issues of transferring gunshot residue in which if you have residues in your hand, it could be because you fired a gun or because you were at the vicinity of a firing event or because for some explainable reason you came into contact with gunshot residues. Now, one of the things that we have this cause in in the conception of this project is that we have faster technologies, that it will take only a few minutes to do analysis. Now we have the capability or not only doing hands. So imagine if you have an individual and you wonder that, I mean, whether the person, fire or not had gun you you can do now because this is much faster. You could do more comprehensive cases in which you can sample the hands, but you can also sample areas that are less prone to transfer emphases than you can. They sampled the nostrils. You can sample the ears, you can sample the hair, you can sample the clothing. And that is doable because of the very fast time that takes to process the evidence. So now you have a better understanding of whether that person could have fired a gun or being in the vicinity rather than having second value or started transferred. That might be more limited to the hands or the clothing or that particular way of transfer. So if you have a more comprehensive case management and interpretation I think that that can help in the overall assessment of the interpretation of countries. Which is complex, but I think has a lot of value in the criminal justice system. So if we can improve the ways that we can do probabilistic models on how we can use that and use fas technology to be able to do with more comprehensive studies, I think that we can eventually increase the confidence of our conclusions.

Megan Grabenauer [00:41:34] You learned anything that really surprised you or was very unexpected?

Tatiana Trejos [00:41:38] So we always learn different things in our research,have to work on different challenges as well.

Tatiana Trejos [00:41:44] But I think one of the most surprising aspects that we have found in the research is one of my students is creating gunshot residue standard. So she's creating microscopic particles that contained the formulation of standard and non toxic ammunitions. So we are capturing those. We are characterizing them by different legal methods to learn more about their compensation so that eventually we can use this as standard sort of quality control in the forensic laboratories and also to do more systematic studies of transparent persistence, because eventually we will know this is standard that we create in the laboratory has the number of particles that volume and these particular composition. So in doing that, we had to characterize several then in nontoxic combination. So what we found surprising is that a lot of standard ammunition, didn't have the standard markers when we did the characterization, and a lot of led free ammunition or at least label as led free ammunition still have led in many of the heavy metals. So it is a challenge for us as forensic examiners because the composition is very changing and the formulations, but also the labeling, the chemical composition of those combinations sometimes is not representative of what the composition comes from. So that has being a little bit surprising for us. We have started with 10 nontoxic ammunition and I think half of them had heavy metals on it. So we had to go back and tried to get more to really get a true representation of what a nontoxic combination is.

Tatiana Trejos [00:43:36] So just to give you an idea of some challenges that we have experience.

Megan Grabenauer [00:43:40] I think we're just about at a time for our conversation. But before we end, were there any other final thoughts that you wanted to share with our listeners?

Tatiana Trejos [00:43:48] So I think the take home message I would like to share with the audience is that as with any other science, we will always be exposed to new challenges and changes in our discipline. So we have to adapt to those challenges and make use of the resources to modernize and improve our approaches.

Megan Grabenauer [00:44:04] All right. Well, Dr. Trejos, thank you again for sitting down with just science to discuss your grant today. It's a pleasure talking with you.

Tatiana Trejos [00:44:11] It's been a pleasure. We have been honored to be able to share that with you.

Megan Grabenauer [00:44:15] And I'd also like to thank you, our listeners, for tuning in today. And for more information on today's topic and resources in the field of forensic science. Visit forensiccoe.org. There you'll find additional webinars, guidance documents, reports and conference information. And also, please follow the FTCOE on Facebook, Twitter, LinkedIn or sign up for our newsletter for release dates on upcoming resources.

Megan Grabenauer [00:44:38] I'm Megan Grebanauer and this has been another episode of Just Science.

Voice over [00:44:45] In the next episode, just science interviews Dr. Travis Rush, a post-doctoral research associate at Texas A&M University, about extreme temperature fluctuations and their effect on blowfly development. Opinions or points of views expressed in this podcast represent a consensus of the authors and do not necessarily represent the official position or policies of its funding.