UpClose

with Sam Mason

Her office may be at State University of New York (SUNY) Fredonia, but Dr. Sherri "Sam" Mason has spent the last two years traversing the Great Lakes in hopes of quantifying how much plastic pollution is in each. Dr. Mason and her research team became the first to investigate plastics in this fresh water ecosystem when they sailed across lakes Erie, Huron, and Superior in 2012. Phase two of the project ended last summer with samples from lakes Ontario and Michigan—work done in part with Illinois-Indiana Sea Grant. Her work has put a spotlight on plastic pollution in freshwater systems and the patterns and potential impacts of this emerging contaminant.

IISG sat down with Dr. Mason to talk in detail about her field studies, the results so far, and some important questions that still need to be answered.

How did you become interested in plastic pollution in the Great Lakes?

I moved from Montana to Fredonia, which is along Lake Erie, in 2001 for a teaching job at SUNY. When I was given the position, my primary responsibility was teaching physical chemistry, but they also had me teach a non-major consumer chemistry class. Since I have been interested in environmental chemistry since the age of 12—I got into chemistry because of acid rain—the course became about not just the chemistry of things like shampoo and fireworks but also about environmentally-related topics like genetically modified foods, consumer waste, and climate change. This was 2001, right around the time of the Great Pacific Garbage Patch discovery. So I started teaching about plastic pollution in that course. It is a great mechanism to get students interested in science because they know plastic.

When I took over the environmental sciences program in 2006, I started running the program differently. In 2010, we were contacted by the *US Brig Niagara* about teaching a class aboard the ship. It is an environmental methods class that teaches the students about the Great Lakes and how we monitor the lakes while living on this really cool boat. As soon as I heard about it, as much as I was excited for the students, I thought, "I want to go." I have always loved chemistry. It is definitely where my heart is, but it has always been about chemistry in the environment. To teach students who usually struggle with chemistry but are really interested in the environmental side of things was very nice.

At that point, I was doing atmospheric stuff. I came on board to talk about deposition in the Great Lakes because that is the primary way that many contaminants get into the lakes. I spent a week just sailing, and that was the first time I had ever been on the lakes. What that course did for me is exactly what we were hoping it would do for the students—I realized how beautiful the lakes are. They are just amazing.

Living along the shores of Lake Erie, with all the dead fish and algae, you really don't get an appreciation for how beautiful the lakes are until you get out on them.

It was out on the lakes that I started thinking, "I wonder if there is plastic in the water." I guess that is how science happens, right? You get a question that at the time seems like just a normal question. It started off as just a fun project to do with the students—"Let's drag a net through the water and see if we can find plastic."

Is that why you started your sampling in lakes Superior, Huron, and Erie? Because that was where the *Niagara* was going?

Yeah. When we run the course, it's up to the boat where we go. It is not up to us. They have certain port commitments, and we run the course based on those commitments. It just so happened that in 2012 we had this idea and then saw the schedule and thought, "Oh, this will be really awesome." We were going to start in Lake Superior and follow the flow of the water, and that was really ideal.

During that time, we got a price quote for having a trawl made, and it came back at $12,000. We didn't have that kind of money. This was supposed to be just for fun. Doing some searching online, I found that 5 Gyres [an advocacy group focused on reducing plastic pollution] had this travel trawl program, so I contacted them. I knew of Marcus Eriksen and Anna Cummins from all the stuff that I had read and seen with regard to oceanic plastic pollution. It was serendipity. I had this idea, and one of their cohorts, Stiv Wilson, had been thinking about the same thing and had mentioned it to Marcus. So, rather than just loaning me a trawl, we decided to collaborate. That is how it all developed.

How did you decide where to sample?

It was pretty random. It was different than on *Free at Last* [the boat used for the IISG-funded sampling trip on southern Lake Michigan]. That boat is relatively small, and it was charted for that purpose. The *Niagara* is a very big vessel, and you are under time constraints. Every morning we would sit down with the captain and look at the weather, the winds, where we needed to be, etc. We would plot everything out on a daily basis.

The last two samples were really close together because we could actually see a lot of plastic when we pulled in the first one. We thought, "Let's throw it in again." Before that, we had planned to take one last sample—sample 20— and be done at a nice even number [the final study had 21 samples]. We did the same kind of thing when we were coming out of the Detroit River. There were quite a few right there in a row because the first one we pulled in had a huge piece of plastic. We thought, "This is a good area." At that point, the process was a lot more haphazard.

It was more planned when we were in Lake Michigan in 2013. We had a lot more time on the *Niagara* coming from the Straits of Mackinac to Chicago, so we could sit down and plan it out. We did these big zigzags. But then we got pressed for time, so we started doing smaller zigzags, knowing that we were going to have the *Free at Last* and could use that boat to get more samples. That was a lot more coordinated. We had an idea of where we wanted to sample based on dominate lake currents and used the different vessels and legs of the overall expedition to sample in those locations.

Then, when we were out on Lake Ontario, we kind of circumnavigated the outside of the lake. We were on a smaller boat there as well, so we could get closer to shore—the *Niagara* can't get that close. We were closer to the sources, where there was less dilution. That might be why we see such huge numbers in Lake Ontario.

What were the results of the first study on lakes Superior, Huron, and Erie?

We did five samples in Superior, eight in Huron, and eight in Erie. The counts in Lake Superior were slightly higher than in Huron. But we didn't have many samples in Superior, and we were closer to shore than in Lake Huron. I think that is part of the reason the numbers are higher in Superior.

Despite Lake Superior's reputation for being the least polluted lake?

Yeah. I have been in touch with the fisheries division of the US Geological Survey (USGS) that does a fish survey up there. They have noticed plastic in the fish there—just anecdotally. This was interesting to me because the local fisheries unit, run by the New York State Department of Environmental Conservation, doesn't look at stomach contents. They bring in the fish, measure the length and weight, pull out this bone that will age the fish, and throw the rest overboard. Mark Vinson up in Lake Superior does, though, so we are starting to talk with him about looking at fish guts more systematically.

So, as pristine as it is, there really is plastic up there. But because there are relatively few people that live around Lake Superior, and it is the beginning of the water chain, you would expect the counts to be lower. They were a little higher than in Lake Huron but nowhere close to what we found in Erie.

What was really interesting was Lake Erie. Ninety percent of the plastic that we found in 2012 was in Lake Erie. That was interesting and not terribly surprising. Lake Erie is the most densely populated of the Great Lakes, so there are more direct inputs. But on top of that, you have all the stuff that is flowing into Lake Erie. Continuing with that hypothesis, Lake Ontario should be higher, and the numbers we are getting there are higher actually. The highest count we got in Lake Erie was 450,000 particles per sq. km. We have one sample in Lake Ontario that is over a million.

Are these mostly microplastics?

Yeah. There are two interesting things here. One is that some of the counts we are getting in Lake Erie are among the highest in the world. The other is that we found a higher percentage of smaller plastics than what's been found in the oceans. What we find in the oceans is typically 1-5mm. The Great Lakes are essentially upstream from the oceans, so I thought we were going to find bigger things. If we found anything, I thought we were going to find things like plastic bags and bottles. We did catch a bottle and bag in Lake Ontario, but I thought that was going to be the majority of what we found. Instead, it was the exact opposite. Eighty percent of the plastics from all of the lakes were in the smallest class size—.33-1mm in size.

Are things in that class size visible?

They are, but when you are looking in the net, you don't really see them because there is so much living material—algae, zooplankton, plants, and even little fish. You can kind of see pieces. In the very first sample we pulled in, I saw a little piece of styrofoam as soon as I looked in the net. It is possible to see it, but it can be difficult because the lakes have a lot of plant life, zooplankton, and algae.

It's when you get to the lab that things get really interesting. It is almost like magic, especially with the new process we are using. We are doing a wet peroxide oxidation, so you are oxygenizing the living stuff away. You can watch the zooplankton and all this stuff just disappear.

Leaving just the inorganic material?

Leaving the polymers behind. All of a sudden you see these little bits of colored plastic bubbling around, almost like in a lava lamp. The students really get into it because it can be a lot of fun.

These large counts of little plastic particles have been the most interesting part of the work. I don't think anybody was really expecting this. I certainly wasn't. And then the question was, "Where are these things coming from?"

Did these pieces start out small, or are they from larger plastics that broke down?

Those are the two basic sources. You either have direct emission or you have plastic items that were broken down—photodegraded along the way. We see both in the water. We found little plastic fragments that look jagged and ridged under a microscope. We can tell they were part of something bigger. But the more interesting things to me were these perfectly spherical plastic beads. We look at those and can tell that they didn't result from something larger. Those are beads.

Are there more beads than jagged pieces?

There is a higher count of beads, yes. In the 2012 data there were more beads than jagged pieces—more pellets than fragments. 2013 is not quite the same. There are still a lot of pellets, but we are seeing more fragments. It will be really interesting when we pull all the data together and compare the different lakes.

The highest pellet count was definitely in Lake Erie. For some reason, maybe because there are so many people, there may be more pellets in Lake Erie than in the other lakes. That is interesting.

One of the things that we are interested in is whether the plastic leaves the Great Lakes and goes into the ocean. Or are we plasticizing our beaches? I don't think you could look at the beach and just tell. These pieces of plastic are very tiny. They are the size of a grain of sand. Could it be in our beaches? Could it be in our fish? It could be in all sorts of things.

We are still doing quality control on the data from 2013, but then we will get into our data analysis and start looking at how the numbers compare. I want to get more samples out of Lake Superior because we only have five from that lake right now.

You had two sites in Lake Erie that really pulled up the average. Could those be outliers?

Like I said, when we pulled in sample 20, we knew we had to throw the trawl back out and do an immediate check. It was surprising.

I think those high numbers are partially because of the current. It may be that the currents were just pushing stuff together. We were also closer to the shore and in between some pretty big cities where you have a lot of wastewater treatment effluent and a lot of combined sewage overflow events that could have also contributed to those really high counts.

Given the counts we are seeing in Lake Ontario, these sites are definitely not statistical outliers.

What are you seeing in the initial data from lakes Michigan and Ontario?

Michigan is much more like Lake Erie in terms of the counts. Lake Ontario—well, in 2012 Lake Erie blew Lake Huron and Lake Superior out of the water. Lake Ontario is blowing them all out now.

Lake Ontario is downstream from the other lakes, right?

It's the last lake before the water discharges into the St. Lawrence Seaway and the Atlantic Ocean. We have samples that we took in the St. Lawrence Seaway [a series of canals used to travel between the Great Lakes and the Atlantic Ocean]. Those counts are also very high.

Do the counts get consistently higher as you move downstream?

I don't know if they get consistently higher. That is something we will have to look at more closely. We are looking at the numbers now.

How do you process the samples?

Undergrads [laughs].

How long does it take to process each sample?

About a day or two for the basic processing and counting. The students can only be in the lab for so many hours. The most tedious part is counting the little plastic pieces and looking at them under a microscope to determine if they are a fragment, pellet, line, or foam. Foam is really hard, especially when they are that small—just to distinguish if it is foamy or not. That category is a little more difficult. At that size, I almost wonder if everything is a fragment.

Is there an established definition for these categories, or are you having to create those as you process the samples?

People have been doing this in the oceans, and we are using their definitions and categorizations in order to maintain uniformity so we can compare numbers.

The newest part is the wet peroxide oxidation. In 2012, we were just using salt water to float the plastic out of the water. I think that is how we ended up with some ash particles that were originally misidentified as plastic. We are not seeing that with this new process. This process actually oxidizes all the biological stuff away, which makes the samples much cleaner.

Right now, the students count the particles, then I go through and do further analysis. The additional analysis can take quite a bit longer. This year, we plan to do some FTIR analysis [a method for profiling polymers using an infrared light] so we can determine if the particles are polyethylene, polypropylene, or any of the other types of polymers out there. For that, you have to do one particle at a time—put a particle in, take a scan, and decide which it is. The process is tedious and takes a lot of time, but the information is important.

Which samples will you analyze?

The samples from both 2012 and 2013. We will probably do a 20 percent representative sample, but we are not sure what that means exactly. We are still trying to figure out whether that is 20 percent of all three different size classifications or just microbeads? This is going to be a lot of work. If we are talking about 1,000 plastic particles, 20 percent is 200 particles. That is going to take some time.

Do all the samples from Lake Ontario have higher numbers or just a few?

The counts that we got at the two highest sites in Lake Erie are more like the norm or average in Lake Ontario. Again, I think there is an additive effect. Those two sites in Lake Erie were our two easternmost samples. So, if all the water is going that way, you are likely to see more buildup.

I am really excited to be going out on the *R/V Lake Guardian* this summer because we are going to be doing some sampling on Lake Erie even further east than in previous years. We will be able to almost duplicate some of the samples we took in 2012. It will be pretty cool to see the variability.

Was there a difference between the counts in southern and northern Lake Michigan?

Not as much as I thought there would be. I thought there would be a big difference north to south because of the currents, but there doesn't seem to be as big of a difference. It is more mixed, which does align with the fact that the retention time in Lake Michigan is so long.

What do we know about where these plastics are coming from?

Those perfectly spherical plastic particles—we really do know that those are coming from consumer products like facial and body washes. We are seeing those coming through wastewater treatment plants. That is a study that we have been doing and will continue to do. Hopefully we can get enough samples done to get the work out this summer. I know people want to see those results. They want to be able to reference a paper as opposed to personal communication. But we are seeing that these things are making their way in through the wastewater treatment plant. I feel very confident about that.

Every time I talk about treatment plants, I just have to make this point: it's not their fault. The issue isn't with the design of the wastewater treatment plant process. They were not designed for this. It is not an issue with the operators. There is nothing they can do. The problem is with the design of the products. You don't put plastic beads that last forever in something that you use for 30 seconds while washing your face. That is really poor product design.

As for the fragments, those are obviously coming from the breakdown of bigger things. There is not a person in the Great Lakes watershed, I think, who can't remember a time they saw a plastic bag stuck in a tree or bush. We see plastic bottles and caps on the side of the road, and most people don't want to pick that up—it's trash. We walk down the street the next day, and it's not there. We don't think about where it ends up, but the reality is that some of it ends up in the water.

It would be nice if we could be more specific. We are looking at maybe using biofilms—little organisms that attach themselves to the plastic—as a way of measuring how long a plastic particle has been in the water.

The more organisms there are the longer it's been in the water?

That is what we are thinking. We are also thinking that if plastic makes its way through a wastewater treatment plant, which uses organisms to decompose the waste, those plastic pieces would maybe have different organisms attached to them compared to plastics that didn't go through a wastewater treatment process. That is a possibility.

How much do we know now about where they are going?

There are still a lot of questions. Is there a way to determine how long a plastic has been in the water, where it was, and its trajectory? It would be interesting to see if that is possible. That is one of the things we are thinking about. We are working with researchers at Loyola University—John Kelly and Tim Hoellein—on topics like this.

There are a lot of questions about the sinks [ways chemicals are removed from an environmental system]. As I mentioned, are they washing up on our beaches? Are they sinking? Where are they in the food chain?

The Sea Education Association put out a paper looking at particles in the Atlantic Ocean showing that biofilms can actually build up on them enough that they start to sink. It increases their density, and they sink. So, is it possible that the floating plastics, which are what we have been talking about, sink? I am really excited to do some sediment samples. I took my students out to Lake Erie for fun, and we grabbed some sediment samples. And USGS took some sediment samples while doing their stream monitoring this fall and sent those to me. We are going to start looking at that too. Half of the plastics we make float and half sink. So, in theory, what we are seeing on the surface is mirrored on the floor. But it may be that there is more on the floor because they're sinking.

What we are most worried about is that these plastics are making their way into the food chain, so we are looking at fish too. That is the big project.

You are just starting that project?

Yes. We are going to work with our local fisheries unit. They are going to collect the fish guts for us, and we are going to analyze them. We are also working with the Ohio unit of the US Fish and Wildlife Service to look at cormorants, a species of waterfowl that eats fish. As part of their culling program [a standard wildlife management practice], they are going to donate some birds to us, and we are going to look at their stomach contents. The culling happens in April and May, and the fish samples will be taken this summer. We are writing grants right now to get money to do these things.

What are the concerns about plastics in the food chain?

Well, you have the direct impact on the organisms. If they eat plastic, it could satiate their hunger until they starve to death. That is really bad.

But the biggest concern I have is not so much the plastic but the chemicals in the plastic or the chemicals that adsorb onto the plastic. It's the nature of the material that they have to use plasticizers to make the plastic—to make it moldable and all those things. They add these plasticizers, the most infamous of which is BPA [Bisphenol A]. The thing about plasticizers is that they are not chemically bound. They are held within the matrix of the plastic, but they are not chemically bound to it, which means they can migrate and move out of the matrix. So, as a fish eats the plastic, those chemicals could move from the plastic into the organism.

On top of that, we know that the Great Lakes contain all these legacy pollutants, like PCBs [polychlorinated biphenyl]. The ironic thing is that even though they are in the lakes, they don't actually like being in the water. They are very hydrophobic. If they are in the water and then there is a little piece of plastic, they will move from the water onto the surface of the plastic. Then, when the plastic is eaten, those chemicals can desorb into the animals.

These chemicals are toxic. They are known to be carcinogens in some cases, mutagens, or teratogens [chemicals that cause birth defects]. So they not only affect the organisms, but they also affect their off-spring. These are the big concerns. An organism can eat the plastic and continue to live. It then has babies and passes these chemicals onto their babies, which affects their development. That is the scariest thing about teratogens. The fetus is exposed to them from the moment of conception, and they affect that organism from the very beginning. Many of these chemicals are endocrine disruptors, which have been associated with all sorts of things. So, my biggest concern with plastics in the water is the ability for those plastics to act as a means for moving synthetic chemicals into the environment and the food chain.

What work still needs to be done to know whether plastics are a threat to food webs?

We haven't studied it yet, but Lorena Rios-Mendoza from the University of Wisconsin Superior has shown that plastics from the Great Lakes do have elevated levels of PAHs [polycyclic aromatic hydrocarbons] and PCBs. So we do know that those toxins are moving onto the plastics that we pull from the Great Lakes. Now we have to confirm that the plastics are in the fish. Then the next question is whether the chemicals desorb from the plastics into the fish. They have seen that in the oceans. Chelsea Rochman from UC Davis just released a study showing that chemicals do desorb from the plastic into the fish and then affect the ability of that fish to live. We are seeing it in salt water systems, so it is really not rocket science that we are going to see it in freshwater systems. They are different species of fish, but the same mechanisms are likely to hold true.

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