Next Generation Research Podcast

Episode 1: *Radishes on Prozac: exploring how human medicines get into our food*

GILES: How much do you know about where and how your food has grown? Not just where in the world, but the actual ground it grows in the water that feeds it? Not much. I think you're gonna want to hear this.

Laura: 120 years ago, we didn't have any of the synthetic chemicals, which are now present in the wastewaters and the biosolids and the manures.

Laura: The value of the process hasn't changed, but the potential risk associated with it has.

GILES: Welcome to the first episode of Next Generation Research, a podcast which brings you to the heart of the most important and exciting research being done in the uk. Right now, I'm Giles Yo, a scientist from the University of Cambridge, and in each episode, I have the pleasure of introducing you to one of the best researchers working in the UK right now.

GILES: Each of them are part of the Future Leaders Fellowship. The goal of the fellowship is to develop the next wave of world-class research leaders in academia and business. They are all working to solve problems and improve our lives as we know them. This, the very first episode is about the true fundamentals of our daily existence as humans, there are nearly 8 billion of us on this planet, consuming and excreting food at a pace.

GILES: Agriculture has had to rapidly expand to keep up with growing populations, and with that has come workarounds to ensure that the growth of crops keeps pace with how quickly we can eat them. Plants need water, sunlight, and nutrients to grow. But not all corners of this fair Earth have these three things in perfect quantities.

GILES: We have developed systems to enable large scale agriculture. One example is that we pump a lot of extra water into the process to make up for insufficient rainfall. In some countries, this is also known as irrigation. Another large component are chemical fertilisers. Since they were industrialised in the late 1800s, they have become crucial in supporting the plant's need for nutrients.

GILES: Unfortunately, chemical fertilisers are not without their problems. They're made from minerals extracted from rock, which is a finite resource, and political unrest and war makes accessing that mineral rich rock very expensive and difficult, such as the situation in Ukraine. Our over-reliance on fertilisers has broken our ties with traditional farming techniques, which prioritise soil health.

GILES: So it really is time to find another way to produce good crop yields with minimal environmental impact. And this is where the reuse of materials that already contain these nutrients can come in. These are things such as manure, slurries, and biosolids from wastewater treatment plants. In other words, what we collectively flush into the sewage systems millions, billions of times every day.

GILES: To some, this might sound rather disgusting, but if we don't reuse them, they have to be disposed of anyway, which has a heavy financial and environmental cost. Whilst the reuse of waste products for agriculture is a great thing, the scale at which these need to be applied in order to replace artificial fertilisers has not been heavily researched.

GILES: Do we know enough about how these processes are impacting our soil's health and in turn the health of the plants we are growing? One of the scientists trying to answer these questions is the focus of this episode. Dr. Laura Carter is an associate professor in soil and environmental chemistry in the School of Geography at the University of Leeds.

GILES: Her current research project looks at synthetic chemicals present in our waste, things like human medicines or antibiotics for animals. The technical term for these are contaminants of emerging concern, and Laura is interested in whether they are a risk to the health of our soil and plants.

Laura: Some of the earlier research that I was involved in was able to determine that synthetic chemicals, such as pharmaceuticals that are present in soils can be taken up by plants.

Laura: So when you take a pharmaceutical for the treatment of a disease or alleviation of a symptom, and a small proportion of the chemical gets used in the body and the rest is eliminated in the waste stream, and this waste stream then enters a wastewater treatment plant and wastewater treatment plants are not specifically designed to remove these chemicals.

Laura: The chemicals are then transferred into the agricultural environment when you are using these materials. So if you take a drug to elicit a response in the body, that potency isn't lost when these chemicals enter the environment, and this then results in potential risks to non-target organisms or crops, for example, that could take up these chemicals.

Laura: So we are interested in thinking about the fate of the chemicals following the application of these materials to land, and then what the risk is to soil and plant health.

Laura: So from a human health risk perspective, the amount of pharmaceutical that's actually present in the crop is very small. So even though the concentrations may be small, I think it raises a lot of important questions as to what do those small concentrations mean in terms of potential for human health effects?

Laura: And desk-based exercises have suggested that this potentially isn't a human health risk because of the small quantity of pharmaceutical that's

present. But interestingly, some research in Israel has shown that people that are consuming wastewater-irrigated-produce, have traces of antiepileptic medication in their urine.

Laura: And this is following the consumption of the produce. It's not from the use of the chemical by individuals. They've been able to trace it back to the consumption of the irrigated produce.

GILES: Laura recently visited one of her peers in the field, Dr. Mike Williams, who is a senior research scientist at Australia's National Science Agency.

Mike: Um, I've always been interested in contaminants in general in our wastes. Not just wastewater or biosolids, but other types of waste, tire waste, any other organic waste, like compost. So I'm always interested in understanding how the contaminants contained within that waste will potentially interact with the environment, whether it's.

Mike: A natural environment or an agro ecosystem, what the fate of the contaminants are and, and whether they present a risk in that particular type of environment.

GILES: Mike is based in Adelaide in Southern Australia, where irrigation with wastewater is an essential feature of agriculture. Like Laura. He is also interested in how the potential contaminants in this water could affect the environment.

Mike: We have a lot of dry land. A lot of the agriculture around Adelaide is irrigated because we don't have a reliable source of irrigation. Most of the water would come from either rainfall, which we get during our winter months, during our summer months, that needs to be supplemented by the Murray River, which is Australia's main river, flowing past Adelaide. We also use quite a bit of. Recycled wastewater of around 2000 gigaliters of

wastewater produced in Australia per year. Australia reuses around 250 gigaliters of that for wastewater. Irrigation.

GILES: A gigaliter is 1 billion litres. That's a lot of water.

Mike: I think the number around Adelaide is around 30 to 40 gigaliters per year, and that goes on to market gardens in the north of Adelaide, which is our state's food bowl.

Mike: We also have a lot of grape growing for wineries in the McLaren Vale. Various other schemes like orchards and flower growing types of horticulture as well.

Laura: So recycled water is a very important resource. Has that always been the

Mike: case? I think the trend has been fairly stable over the last few years. There has been an expansion into the northern Adelaide plains, and a lot of that has to do with social acceptance of irrigated wastewater.

Mike: We've always produced it. But now I think there is more social acceptance. There is more need for wastewater with a very variable climate that we have even in a good year. We do have a long, hot, dry Mediterranean type summer, and that water is needed during

Laura: those months. Do you use biosolids in Australia?

Mike: Yes, 3 million tons per year are produced. The majority of that, around 90% is land applied, whether through mine, site rehabilitation or agricultural use, which is around 70% of that total, and the rest of it is land filled, so the majority of it will be applied to land at some stage.

Laura: And in agricultural systems, that's for the benefits of nutrients

Mike: mainly.

Mike: Yeah. Yeah. Australian soil isn't particularly nutrient rich, not compared with European soils. So it has a, has a strong benefit in that case.

Laura: In the future, with the changing climate, what do you see in terms of the reuse of resources and the recycling of materials in Australia? Do you see anything?

Laura: Changing in terms of the strategy or more demand on these resources that we're already using.

Mike: Yeah, so I guess in terms of political climate, everyone knows about circular economies now, so in general, Waste reuse is becoming more and more important, especially with a lot of countries in Asia now refusing to take out waste, which is fair enough, so we are needing to process them onshore and land fillings not such a big option.

Mike: Similarly with the waste water and, and bio. Solids with climate change becoming more of an impact. Last year, Australia suffered extensive flooding. Probably two years before that, we suffered a long drought with bush fires. So the climate's obviously changing a lot and to ensure we have a stable source of good quality water and nutrients to add to the soil, obviously we'll need to rely more and more on our waste products for that.

GILES: Back in the warren of labs in the geography department at Leeds, Laura and her team are studying how common contaminants could be affecting the plants in our soil.

Laura: in the lab we have controlled growth facilities where we can replicate what's happening in the environment, but in a controlled manner.

Laura: As part of the fellowship, we are designing a series of studies to link the presence of the chemical in the plant with an effect.

Andrea: These are radishes. We chose radishes because, it's very easy to look at the different parts of the plant, like the root, the stem, the bulb, the part that you eat. And they are also easy to grow and they grow fast. Hi, I'm Andrea and I'm a postdoctoral researcher in environmental chemistry working with Laura Carter.

Andrea: So we are in the research and development lab at the geography labs. Uh, in here there is a control growth chamber that can control temperature and humidity. And here is where we keep the plants that we are growing to test the effect of different pollutants. What we are doing is growing some plants with controlled synthetic wastewater and then some plants that have as well irrigation with the controlled synthetic wastewater, but with some added pollutant that is, uh, naturally occurring hormone.

Andrea: We are using concentrations that would be found in scenarios where wastewater is reused for irrigation, and we are harvesting them at different time points to test the effect during the development of the plant. So we also have another part, same set up with some radishes in some pots, and we have three groups.

Andrea: So one control group irrigated with synthetic waste water, one group that is irrigated with synthetic wastewater and the hormone estradiol. And then one group that is irrigated with as well synthetic waste weather, and non-steroidal and inflammatory drug.

Andrea: The reason we chose these pollutants are because they are very commonly found in the environment. And for example, estradiol is a hormone that is excreted naturally by women, so it can't be stopped. So it will be found in their urine and then therefore, in the wastewater and wastewater treatment plants aren't adapted to remove this effectively.

Andrea: Same with the other drug. So that is why we are doing this experiment to understand the effects, and we are letting them grow all the way up to seed. And then we are collecting the seeds and we are going to replant them and see if there's any effects in like the offspring of the plants. And for all of the plants.

Andrea: What we are looking at is where the pollutant goes in the plant. So this is staying in the radish, is it staying in the roots? Is it in the stem, in the leaf? This experiment is more about sub lethal effects. So what that means is that we are not expecting. The plants to die at these concentrations that are naturally seen in the environment.

Andrea: But there can be effects that can affect, for example, things like the circadian rhythm, which means that maybe the flower comes at a different time, then doesn't match with pollinators. Then causes sort of knock on effects in the environment. So it might be, yeah, very small changes that you might look at the plant and think it's fine, but it's important in the overall picture of the environment.

Laura: Even though our work is laboratory based, what we need is an idea or an understanding of that realistic environmental exposure so we can help put our results into context. And in the UK we really don't have large data sets, which. Demonstrate the presence and the concentrations of these pharmaceuticals in agricultural environments.

Laura: And this is really important to make sure that the work that we are doing in the lab is focusing on the chemicals of concern using concentrations that are environmentally realistic.

Laura: So we started the spade campaign, and that has involved going to farms, which are using biosolids and manures and slurry on their lands to collect soil samples to then analyse them. So getting farmers engaged in the research and letting us collect soil samples has been certainly a

challenge because we didn't want to come across as we want to collect these soil samples and we want to tell you everything that's wrong with your soils. And I think that's certainly a way that it can be interpreted, but I think what's worked best is having open conversations. And one of the best ways is going and speaking in person.

GILES: Laura went to visit one of the farmers she's been working with to improve our knowledge of what is present in soil around the uk.

Laura: So we're on our way to visit Chris, who is a farm estate manager for a large farming operation in Yorkshire. It's a mixed farm, so there's arable crops, but there's also livestock production.

Laura: We have worked with Chris on a project to try and work out what. If any contaminants are present in soils. So Chris uses manures, um, on the land at the farm for fertilisation purposes, and we're trying to work out by using the manures is this transferring contaminants to the soil? That is really useful because it enables us to think about the work that we are doing in the lab at a field scale.

Chris Farmer: These are Jerseys jersey cows, beautiful dairy cows, and they're very, very intelligent, very sensitive. They like things on their own terms. You go to stroke them and they back off. But if you stand here, they come to you. So they, but they're lovely animals. I'm a farmer estate manager in South Yorkshire for a dairy and farming business, and also co-facilitate the Dearne Valley Farmers Group, which is a group of about 35 farmers looking at more sustainable farming methods and focusing on environmental impact and profitability of those businesses.

Chris Farmer: In the summer, you've got cows grazing on the grass. Their manure is directly going onto that land. In the winter, they come into the sheds and they're put on. Straw bedding. That straw has come from our

arable crops, which we harvested in the summer, and that builds up into a large source of Farm Avenue.

Chris Farmer: Every so often. We remove that from the sheds, and that goes into a muck pile in the corner of one of the fields. It's moved around to prevent soil damage from being in one place for too long, and then it is typically spread onto our land and incorporated before we drill our next wheat or barley or oil seed rape.

Chris Farmer: Those crops then grow. They're obviously taking some value from the nutrients within that manure and that organic matter of the straw breaking down into the soil has a positive contribution to the soil health and soil organic matter content and then we harvest the crops the cycle starts again.

Chris Farmer: The animals are an integral part of fertility and organic matter within the farming system, whether that's them and applying it directly to land by moving around and grazing or from their bedding and the farmyard manure in the sheds. If you look at the operational carbon footprint of a farm, a big ticket item on that list is.

Chris Farmer: Bagged chemical fertiliser, standard N fertiliser, and the carbon footprint of that roughly is about three and a half tons for every ton of fertiliser. Everyone now is coming to the conclusion of, okay, how do we look at this carbon footprint? How do we reduce our operational emissions? How do we look at sequestering more carbon into our land?

Chris Farmer: What has also kind of accelerated that thinking was the vast and very fast change of artificial fertiliser prices as a consequence of Russia's invasion of Ukraine, which effectively, you know, From kind of two, 300 pounds a ton, suddenly at 900 pounds a ton. They've come down now, but it was a real wake up call for farmers who are relying on that bought in fertility.

Chris Farmer: So people who are in that position are definitely starting to think, do I need to reintegrate livestock onto my farm for a bit of resilience and natural fertility into my system?

Laura: People in China have been doing this as a practice at a local scale for over a hundred years because they acknowledged the circularity of the system and the return of much needed like nutrients to land. But I think what's changed is the composition of the material. So a hundred. 120 years ago, we didn't have any of the synthetic chemicals, which are, um, now present in the wastewaters and the biosolids and the manure.

Laura: The value of the process hasn't changed, but the potential risk associated with it has. The reason why we got in contact with Chris in the first place was we know that some manures and slurries can contain some antibiotics that are given to livestock. But what we also know is when these materials are applied to land, they can sometimes be transferred into the soils.

Laura: But for example, the different methods of application can have a really strong influence on the behaviour of the chemicals. And so what we were working to do was take samples from a variety of different farms to understand the prevalence, if any of chemicals, and how the different practices might influence the prevalence of the chemical, but it's ...

Chris Farmer: antibiotic use has gone down massively in the uk, probably globally over the last few years, and it has been one of those great success stories only. We're not, we're not perfect yet, and there's still lots to do, but there's been great strides made in terms of use of that since it was highlighted as as a big issue and as well.

Chris Farmer: antimicrobial resistance obviously is a big concern, isn't it? So, Whether it's antibiotics from veterinary treatment or whether it's the

impact of, for example, glyphosate, we know what impact that has on crops. What impact does it have on soil biology?

Chris Farmer: The idea of being circular with animal manures and organic materials such as straw onto land from whence it came is a good idea. The question is, What is in that material? What do we need to do to treat this? We need to understand the impact of all these things, cause fundamentally there are ways of doing this in a really positive, circular way, but we just need to be careful that we've not missed something.

Laura: Part of that may be the development of thresholds, for example, for permissible limits in terms of certain chemicals that can be applied to land. It could be strategies for the storage of manures and slurries. So increased time in a slurry tank has the potential for the chemicals to degrade, for example.

Laura: So we are trying to create, I guess, the knowledge to do that. When we went and collected all the samples, we did it on an anonymous basis. Yeah,

Chris Farmer: anonymization is a big one.

Laura: We were trying to understand baseline levels of contamination, which is really important in terms of understanding then about the risk.

Laura: Potential for risk. But nobody wants to be known as the farm that has found a certain antibiotic in their soil. So we need that data cause that's really fundamental to think about mitigation and to think about policy development in the future, but it can't be done in a manner that risks farming livelihood.

Chris Farmer: I think that farmers feel under significant pressure economically, environmentally, socially, animal welfare. It's a really strange

situation where we have where the food system drives cheaper and cheaper and higher yield and higher yield production. The cheaper you have to produce something, the more potential effects and unintended consequences there are there.

Chris Farmer: A lot of the way that we rear animals and grow crops is a response to market demand and government policy, but it's then strange that farmers kind of get or feel that direct criticism and pressure.

Chris Farmer: I've never met a farmer who doesn't care about nature. They do wanna know about soil health. They do wanna know about these things, but clearly they don't want to give anybody any ammunition for even more criticism. We're currently at a rate now of over one farmer suicide per week in the uk. They need supporting and we need to look at ourselves in terms of our own role within the food system and be careful when just directly criticising without knowing the full facts or being self-aware about how our own choices affect how things are grown and reared.

GILES: As you're probably gathering by now, Laura and her colleagues are just scratching the surface and there's still a lot left to do.

Laura: The first phase of the fellowship is designed to look at the potential risks arising from this exposure, and I think once you've worked out what the effects are and potentially linked the use of the drug to effects, then you can think about a much wider suite of chemicals to think about which ones are are the ones we need to focus on in terms of regulation.

Laura: The next part of this research, I think moving into the, the longer term is thinking about treatment technologies and approaches to reduce the concentrations and the levels of these contaminants in the resources themselves, but also in the environment so that they're not causing effects. So how to clean up or to treat the biosolids and the, and yours so that they

remove or decrease the concentrations of these chemicals so that they can be used in a safe manner.

GILES: So how are we supposed to feed 8 billion people in the world safely? Without destroying the planet. This idea of reusing waste, which we produce in copious amounts to actually feed back into the soil is clearly a wonderful idea. But without the work, you know, of scientists like Laura trying to understand if this is safe, then we could actually end up doing more damage to the world than any good at all.

GILES: I think meeting and listening to people like Laura working on things that actually matter directly to me about the food that I eat has been very inspiring.

GILES: A huge thanks to Laura and also to Mike, Andrea and Chris for introducing us to this world. If you wanna find out more about Laura's work, you can follow her @CarterL_J on Twitter. And we will link to her university page in the episode notes next time we travel all the way to Samoa to visit with Jenevieve, who's working to understand the causes of intimate partner violence.

Laura: People have looked at the whole world, but they hadn't looked at the worst case scenarios. And so you're interested in seeing what's happening in the worst case scenario, and why do some countries have such a high rate of violence?

GILES: This podcast is supported by the Future Leaders Fellows Development Network, you can find out more about the Future leaders Fellowship you can follow

GILES: I'm Giles Yeo and you can follow me on Twitter and Instagram @GilesYeo. The producer is Hester Cant, the executive producer is Freya

Hellier, the sound engineer is Morgan Roberts. And thanks to Oliver Mitten and Laura Carter for their additional support.

Thank you for listening to this first episode of Next Generation Research.

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