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Episode 92: Cleaning Up The Mess: Bioremediation in Antarctica

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VOICEOVER
Welcome to Up Close, the research, opinion and analysis podcast from the University of Melbourne, Australia.

SHANE HUNTINGTON
Hello, and welcome to Up Close. I?m Dr Shane Huntington. The presence of environmental contaminants is a significant problem around the world. Many contaminants have major consequences on local habitats and wildlife, in some cases causing near complete destruction of pristine ecosystems. From oil spills to soil contamination, bioremediation is seen as a useful biological method in trying to return environments to their original conditions. In extreme environments such as Antarctica clean-up operations are particularly challenging especially when biological solutions such as remediation are used. To address this today we are joined by Dr Kathryn Mumford from the Department of Chemical and Biomolecular Engineering at the University of Melbourne, Australia. Welcome to Up Close, Kathryn.

KATHRYN MUMFORD
Thank you, it's great to be here.

SHANE HUNTINGTON
And later in the show we will be joined by Dave Gurney, direct from Australia's Mawson base from the Australian section of Antarctica. Kathryn, let's talk about contaminants first up and the sorts of environmental contaminants that we find. Can you give us a few examples of what's out there?

KATHRYN MUMFORD
There are a wide range of contaminants that we find around the globe, these include petroleum hydrocarbons, heavy metals or nutrients, excess nutrients in the environment can also be a source of contamination.

SHANE HUNTINGTON
And what are some of the effects of these contaminants in the environment? I mean

obviously some of the heavy metals sound potentially poisonous both to us and the ecosystem but what other things occur as a result of these contaminations?

KATHRYN MUMFORD
Well that's correct. Heavy metals are toxic to a lot of marine life and they're also toxic to a lot of plant life and they tend to accumulate in the systems. Also fuel contamination, it's the toxicity issue that we tend to find in the ecosystem.

SHANE HUNTINGTON
Your area of expertise is bioremediation. This is something that people are pretty excited about as a way in which we can clean up the environment. What exactly is bioremediation? It's been around for a long time hasn't it?

KATHRYN MUMFORD
Well bioremediation is the use of nutrients or oxygen or other mechanical means to accelerate the degradation or the sorption of the contaminant itself.

SHANE HUNTINGTON
This involves microorganisms I understand.

KATHRYN MUMFORD
Yes, that's correct. So many microorganisms have functions that can actually degrade things like fuel but often they're limited in some way. A lot of the time in dry conditions or remote areas they're often nutrient limited so they can process a certain amount of hydrocarbon but they're limited by the nutrient content. If you add nutrients you can accelerate their performance and degrade the contaminant quicker.

SHANE HUNTINGTON
This sounds like you're sort of adding fertiliser or something. Is this what's happening?

KATHRYN MUMFORD
That's exactly right. So it's the addition of fertilisers and there are many different kinds of fertilisers for different applications. There's liquid fertilisers if you're not worried about high level water fluxes, there's controlled release fertilisers if the water in the soil is low. So if you actually add nutrients too quickly you actually saturate the conditions and you can kill the microorganism so it's quite a balancing act between all the different components in the system.

SHANE HUNTINGTON
Are these microorganisms the sorts of ones that exist in these environments naturally or are you introducing them specifically to do a certain task?

KATHRYN MUMFORD
Well it can be both. In certain areas where there are no restrictions you can actually seed the area with a particular kind of microorganism to accelerate the degradation. There are different views on how effective this is. Often they find that if you seed the

site, it only really accelerates at the start of the degradation process. And it tends to wane off as they're not accustomed to the climate itself and so they often find that just by stimulating what's present there naturally is the best way.

SHANE HUNTINGTON
Talk us through the process. When you were to say consider a river or an area of contamination what do you do in terms of going in and evaluating whether or not the microorganisms there are capable of doing the clean up?

KATHRYN MUMFORD
Well we'd normally take soil and water samples and we'd cultivate it in the lab adding higher concentrations of the contaminant and seeing if we change the conditions such as nutrient or water content we actually see a reduction in that contaminant. So there's quite set methods for determining that.

SHANE HUNTINGTON
You mentioned in some circumstances you may have to introduce the biological component in this case to do the clean up. Are there risks associated with doing that into an area where it doesn't naturally exist?

KATHRYN MUMFORD
Yes there are risks but often they're added in a confined engineered barrier of kinds so they can't actually migrate out of the barrier itself, but of course you have to be very careful with the kinds of bacteria that you are introducing because there's the likelihood that they could move beyond where you want them to be.

SHANE HUNTINGTON
How complex can the contaminants be? You mentioned heavy metals what's actually happening there with the bacteria, are they able to actually process the heavy metals and break it down into safer components?

KATHRYN MUMFORD
There's some bacteria that can transform it into other components but with heavy metals we tend to use different technology. We use phosphate stabilisation technologies so we're actually locking in the contaminant so they don't actually migrate and either you can leave it there if it's not going to move because it's actually stuck so tightly or you can then on process that material to extract the metal without disturbing the surrounding area and then disposing in a landfill.

SHANE HUNTINGTON
You're listening to Melbourne University Up Close. I'm Dr Shane Huntington and today we're talking with Kathryn Mumford about bioremediation. Kathryn, let's talk a little bit about the size over which you can do this sort of work, bioremediation. What are the limiting factors and just how big does that size get for certain contamination runs?

KATHRYN MUMFORD

Well for instance if you've got a large hydrocarbon spill you don't necessarily need to build the reactive size of it to be particularly large but you might extend the wing so you actually capture the plume to funnel the contamination through the reactive proportion of the barrier itself, but it can be hundreds of metres across.

SHANE HUNTINGTON
Are there scenarios where I guess the danger level is higher and you would be required to bring some of those back to the lab and do them perhaps more intensely in terms of the biological applications you're using?

KATHRYN MUMFORD
That's correct, in more sensitive areas you need to be sure that your technique is going to be adequate for the sites and you don't want to do more harm, so a lot of it is lab based work to make sure that you're not actually going to introduce anything that's going to be detrimental.

SHANE HUNTINGTON
You mentioned earlier that the environmental conditions where this can occur are quite varied so you have deserts, you have extreme cold and so forth. What sort of things do you need to do in order to prepare or I guess enhance the value of these microbes in order to do the job when those conditions are extreme?

KATHRYN MUMFORD
Well we need to be very particular with how we add the nutrients and particular systems that we use and the oxygen sparging technique, so the quantity of oxygen that you actually put into the soil and how far it can migrate over time. Different soils have different pore spaces and so the oxygen that you deliver is going to migrate over different extents of the ground. These are the kinds of issues you also have to deal with.

SHANE HUNTINGTON
How many microbes are sort of used worldwide I guess that are particularly good over a particular range of temperatures that everyone is sort of using throughout the world to do these clean-up operations?

KATHRYN MUMFORD
There is a lot of research into different kinds of microorganisms and what they're best at doing but it is quite at its infancy stage in terms of tailoring a particular microorganism to a particular job. The finding has tended to be what's at the site, you just try to stimulate because there's going to be a component in their colony that will be able to do the job for you. There's a process it's called natural attenuation so where you actually leave the contaminant in the ground and over time the process will occur, but in different areas where it's more sensitive and you need to do it quicker then you do need to accelerate the process.

SHANE HUNTINGTON
You're listening to Melbourne University Up Close. I'm Dr Shane Huntington and

we're speaking with Dr Kathryn Mumford about bioremediation. Now Kathryn, what's going to be the goal of your next expedition down to Antarctica coming up in the next few months?

KATHRYN MUMFORD
Well about five years ago we built and installed a permeable reactive barrier, so this barrier was to capture and degrade a petroleum hydrocarbon fuel. It consists of two wings that funnel the contamination through the reactive zone and the reactive zone is divided into three parts. The first part is a controlled nutrient release zone, nutrients are released into the water. The second part is the hydrocarbon capture zone, so the hydrocarbons will sorb and not be able to migrate further through. So hopefully where the nutrients will pass through, come in contact where the fuel is and hopefully the microbes are growing and degrade the fuel and then excess nutrient will be captured by the third segment of the barrier itself. So this barrier has been in for five years and we've found that the nutrient side is starting to be a bit exhausted and so we're actually going to remove the material and replace it with new materials that we've been developing.

SHANE HUNTINGTON
So this is essentially a biological processing plant in a way and I guess hydrocarbon general contaminants go in one end, what comes out the other end?

KATHRYN MUMFORD
So the fuel will be degraded so there will be no more hydrocarbons. Carbon dioxide will be released as a result of this and as it's an aerobic system the ammonium that we've released in the fertiliser will be converted to nitrate and so there will be a small amount of nitrate, there may be a little bit of excess phosphorus coming out the back.

SHANE HUNTINGTON
And aerobic systems are ones that?

KATHRYN MUMFORD
Are aerated.

SHANE HUNTINGTON
You mentioned carbon dioxide as one of the outcomes here, are the issues associated with the amount being produced in this clean-up operation?

KATHRYN MUMFORD
Some people believe that carbon dioxide should be calculated as part of carbon dioxide emissions from bioremediation purposes and so maybe in theory we should be trying to capture that and account for that but realistically it's very small amounts that would be being produced in this process.

SHANE HUNTINGTON
You're talking about contamination down at Antarctica, what's the source of all this contamination that you're trying to clean up?

KATHRYN MUMFORD
Well the bases in Antarctica are powered by diesel and so as part of that an icebreaker comes in every year and delivers fuel through a long plastic pipe that goes into a number of tanks. As the station requires more fuel they transfer the fuel around the different tanks. On occasion there are leaks or spills that just come from normal operation because also it is an extreme environment so there's freezing, thawing processes putting large stresses on the pipe work and sometimes they have an incident.

SHANE HUNTINGTON
Is contamination also caused by just the fact that there are a large number of people now, I assume 50-plus living down there at the base and I guess producing a certain number of contaminants?

KATHRYN MUMFORD
Well that's also part of it, the more people that you have the more fuel that you require and the more rubbish that's produced that needs to be disposed of. That's correct, if we weren't there then we wouldn't be having the issues with the fuel but there's lots of great reasons that people should be there.

SHANE HUNTINGTON
You've been there before so I'm sure that you have some great experiences there. What's it like working at Casey in Antarctica?

KATHRYN MUMFORD
Oh it's a fantastic experience. Everyone works well together and everyone has their projects to do and have lots of interesting discussions with people about their previous experiences and everyone gets along so it's fantastic.

SHANE HUNTINGTON
When you walk outside Casey outside the base what's the environment like? People have this vision of an ice-covered, snowing constantly, freezing cold environment but tell us what's it actually like year-round?

KATHRYN MUMFORD
Casey is on the ice-free area of Antarctica so in summer it's actually rock and gravel which can be quite deceptive because sometimes you look out the window and because there's no snow you can't actually see the snow blowing when the winds are high. Often people walk out and start getting blown down the street so they've actually got a weather monitor so you can actually see what the temperate is and the wind speed is and also because even if it doesn't look dark and cloudy outside it still can be incredibly cold so you have to be quite careful with what you're wearing.

SHANE HUNTINGTON
Now we were talking earlier about bioremediation being particularly challenging in some environments. I can't imagine many more challenging environments than the one you're describing. What's hard about bioremediation in the Antarctic area?

KATHRYN MUMFORD
In particular, in Antarctica we can't actually introduce microorganisms into the environment to do the job for us, we actually have to stimulate using the bioremediation process. Also we have problems with water fluxes, so because of the large amount of snow melt that we have at the beginning of summer we have high and variable water fluxes through our systems. We also have problems with freeze and thawing, so over the summer you would get wide ranges in temperature which results in freezing and thawing of our barrier material and causes the particles to break up disrupting the particle size and so hydraulics are through the barrier. Also at low temperatures reaction rates or different processes are a lot slower so we have to design our system according to that.

SHANE HUNTINGTON
Is it a never-ending battle with regards to the clean-up operation down there? Are we keeping up or are we getting behind?

KATHRYN MUMFORD
Well we've signed a protocol that any contamination that we produce going forward that we have to clean up so whoever produces it has to clean it up, but we're also looking at past impacts so previous to the 1980s and tip sites and things like that we're also cleaning up.

SHANE HUNTINGTON
You're listening to Melbourne University Up Close. We're joined now by Dave Gurney from the Mawson base which is in the Australian slice of Antarctica. Hello Dave.

DAVE GURNEY
Ah yes, hello.

SHANE HUNTINGTON
Dave, you've been down at Antarctica we understand for quite some time.

DAVE GURNEY
Yeah this year is my second year. I did a year at Casey in 2007 and this year at Mawson I've nearly finished another winter.

SHANE HUNTINGTON
Tell us a bit about what you take care of down there.

DAVE GURNEY
I'm one of two plumbers and we look after all the station's heating and ventilation, the plumbing and water waste treatment as well as all the usual station duties.

SHANE HUNTINGTON
Dave, I assume that you were trained back in Australia on the mainland. How do the requirements for all the plumbing systems and the cooling systems different in an

environment like Antarctica compared to somewhere like Melbourne, Australia?

DAVE GURNEY
That's a good question. A lot of the systems are designed just in case your pumps fail the system can't be allowed to freeze so we have glycol running through the systems. We actually get a lot of waste heat from the diesel generators which we use for power. One of the big things is just being only one of two plumbers you really need to know all the different facets of plumbing which back in Australia you tend to specialise in just one.

SHANE HUNTINGTON
What sorts of things I guess would the researchers down there have problems with if you were to suddenly not be available?

DAVE GURNEY
I guess the biggest ones are heating because if the heating shuts down through a particular building you can get all the services freezing up and then you've got all sorts of troubles or pipes splitting and that sort of thing.

SHANE HUNTINGTON
Is it particularly hazardous doing your sort of work? I can imagine a large amount of it would be outside.

DAVE GURNEY
Yeah during the summer months you try to do all your outside work but during winter if the power fails you just have to replace it, there's nothing you can do you just have to get out there and do it, so obviously frostbite and frostnip and all that sort of thing come into play. Because you've got so many building surrounding you if you come into any problems you just run inside and get warm again.

SHANE HUNTINGTON
Well Dave we wish you the very best of luck with your remaining time down there and look forward to seeing you back here in Australia in Melbourne.

DAVE GURNEY
Great, cheers mate.

SHANE HUNTINGTON
That was Dave Gurney from the Mawson base from the Australian section of Antarctica. I'd also like to thank our guest Dr Kathryn Mumford from the Department of Chemical and Biomolecular Engineering here at the University of Melbourne, Australia. Thank you for being our guest on Up Close today.

DR KATHRYN MUMFORD
Thank you, it was great to be here.

SHANE HUNTINGTON

Relevant links, a full transcript and more info on this episode can be found on our website at upclose.unimelb.edu.au. We also invite you to leave your comments or your feedback on this or any episode of Up Close. Simply click on the "Add New Comment" link at the bottom of the episode page. Melbourne University Up Close is brought to you by Marketing & Communications of the University of Melbourne, Australia. Our producers for this episode were Kelvin Param and Eric van Bemmel. Audio engineering by Russell Evans. Melbourne University Up Close is created by Eric van Bemmel and Kelvin Param. I'm Dr Shane Huntington. Until next time, goodbye.

VOICEOVER
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