Science AMA Series: I'm Jonathan Sakkos, a graduate student in mechanical engineering at the University of Minnesota. I trap bacteria within porous materials for cleaning pollutants from water. AMA!

Jonathan$_sakkos^1 and r/ScienceAMAs^1$

[1]Affiliation not available

April 17, 2023

Abstract

Hi Reddit! I'm Jonathan Sakkos, a mechanical engineering PhD candidate. I'm a member of the Bioencapsulation Laboratory in the Department of Mechanical Engineering and the BioTechnology Institute at the University of Minnesota in Minneapolis, Minnesota. I study bioencapsulation (physical confinement) of bacteria within porous silica gels for cleaning pollutants from water in collaboration with Professor Wackett in the Department of Biochemistry, Molecular Biology, and Biophysics. Bacteria have a wonderful ability to eat many harmful chemicals (especially hydrocarbons) found in water as a result of millions of years of evolution. I study the interface between the biology and the material as well as the diffusion of chemicals within the material in order to harness the unique abilities of bacteria in an efficient manner. We recently published a paper in Biotechnology and Bioengineering entitled "Engineering of a silica encapsulation platform for hydrocarbon degradation using Pseudomonas sp. NCIB 9816-4" in which we encapsulated a bacterium which is known to biodegrade (eat) over 100 pollutants and optimized the material to be as strong and porous as possible while keeping our bacteria happy . Our lab has also studied the biodegradation of atrazine, a very popular herbicide, by encapsulated bacteria. I'll be here at 1 pm ET (10 am PT, 6 pm UT) to answer your questions. Ask me anything about bioencapsulation and what bacteria can do for you! 3 pm CDT: I have some lab work to do, but I'll check back later this afternoon. Thanks for all of the thoughtful questions. 6 pm CDT: I'm signing off. This has been fun and thanks for the great questions!

the
WINNOWER

REDDIT

Science AMA Series: I'm Jonathan Sakkos, a graduate student in mechanical engineering at the University of Minnesota. I trap bacteria within porous materials for cleaning pollutants from water. AMA!

JONATHAN_SAKKOS R/SCIENCE

Hi Reddit! I’m Jonathan Sakkos, a mechanical engineering PhD candidate. I’m a member of theBioencapsulation Laboratory in the Department of Mechanical Engineering and the BioTechnology Institute at the University of Minnesota in Minneapolis, Minnesota. I study bioencapsulation (physical confinement) of bacteria within porous silica gels for cleaning pollutants from water in collaboration with Professor Wackett in the Department of Biochemistry, Molecular Biology, and Biophysics. Bacteria have a wonderful ability to eat many harmful chemicals (especially hydrocarbons) found in water as a result of millions of years of evolution. I study the interface between the biology and the material as well as the diffusion of chemicals within the material in order to harness the unique abilities of bacteria in an efficient manner.

We recently published a paper in Biotechnology and Bioengineering entitled“Engineering of a silica encapsulation platform for hydrocarbon degradation using Pseudomonas sp. NCIB 9816-4” in which we encapsulated a bacterium which is known to biodegrade (eat) over 100 pollutants and optimized the material to be as strong and porous as possible while keeping our bacteria happy . Our lab has also studied the biodegradation of atrazine, a very popular herbicide, by encapsulated bacteria.

I'll be here at 1 pm ET (10 am PT, 6 pm UT) to answer your questions. Ask me anything about bioencapsulation and what bacteria can do for you!

3 pm CDT: I have some lab work to do, but I'll check back later this afternoon. Thanks for all of the thoughtful questions.

6 pm CDT: I'm signing off. This has been fun and thanks for the great questions!

READ REVIEWS

WRITE A REVIEW

CORRESPONDENCE:

DATE RECEIVED:
March 19, 2016

DOI:
10.15200/winn.145830.01028

ARCHIVED:
March 18, 2016

CITATION:
Jonathan_Sakkos , r/Science , Science AMA Series: I'm Jonathan Sakkos, a graduate student in mechanical engineering at the University of Minnesota. I trap bacteria within porous materials for cleaning pollutants from water. AMA!, *The Winnower*

I work in the field of industrial waste water treatment. Does this research have any implications for municipal or industrial waste water plants or is it more geared towards environmental cleanup operations? I understand how it would be helpful to keep the bacteria contained in certain situations but maybe less so in a closed system. Sorry if this is in the paper, but I'm on mobile and the paper wouldn't open. Also, how are you able to regulate the environment (pH, ammonia, etc.) while introducing so many unknown pollutants and chemicals to the capsules?

yeahsureYnot

Thanks for the great questions. In general, we use bioencapsulation as a tool to keep our bacteria of interest in a device so they can continually biodegrade (eat) pollutants. An example would be a flow through filtration system. This does not limit us to specific scenarios. Our silica gel (bioencapsulation system) starts out as a liquid and can be formed into any shape you can imagine.

That being said, the research being done with *Pseudomonas* is more geared towards environmental cleanup, since the chemicals it can biodegrade wouldn't necessarily be found in municipal systems. A huge potential application for this system is cleaning hydrocarbons from the waste water generated by

3:e145830.01028 , 2016 , DOI: 10.15200/winn.145830.01028

fracking. The atrazine project being done by my colleagues is very relevant to municipal systems, since atrazine is regulated by the EPA.

Keeping the bacteria contained has multiple benefits that are not immediately obvious. First, we can contain them where we have a chemical of interest, so that we aren't losing biomass as our system continues to operate. Second, silica protects the cells from external predators due to the extremely small pores, which are typically on the order of 10 nm. That's too small for most harmful things (other microbes, bacteriophages, etc.) to pass through. Lastly, we can control the system to make it extremely efficient and utilize our bacteria fully. In a system which relies on biofilms, this is not the case.

We don't tightly regulate the environment in the lab, except for pH, which is controlled with a buffer solution.

Are there any bacteria that eat/store lead? Could something like this be used in Flint or similar municipalities?

monkeydave

Great question. I think /u/ironmaiden0329 and /u/shiruken answered this pretty well, but I'd like to add to their responses. One fundamental difference in biological treatment of lead/heavy metals is that bacteria don't use them for food (as far as I know). They might chelate the metals into another form that isn't toxic or water soluble. In contrast, most of our work has been focused bacteria that use the pollutant(s) as a source of energy.

How did you choose that particular Pseudomonas strain? I work with several genera from the Burkholderiales that do similar things and the first thing that popped into my head was why?

Also, it's nice to see that engineering and Microbiology still have a good relationship. Cheers!

IronMaiden0329

Professor Wackett, my co-advisor, has worked with *Pseudomonas sp.* NCIB 9816-4 for a large part of his academic career, so we know a lot about what it can and cannot do. It's been extensively studied and it's a good model organism for hydrocarbon biodegradation. It has been shown to biodegrade more than 100 different chemicals with a single enzyme pathway (naphthalene dioxygenase). An additional advantage is that we can grow it directly on naphthalene in non-sterile conditions and it's very robust.

Any work with polychlorinated biphenyls?

molefsky

We have not worked with PCBs, but I believe there are some dioxygenase enzymes which can biodegrade them.

What advantages does your system provide over mycofiltration and mycoremediation?

Thanks.

untumulted

It's my understanding that mycoremediation is mainly used for treatment of soil. Our system is best suited for treating water pollution, though I can fathom it being applied to soil as well. The main advantage we gain by encapsulation is control over the whole system. We select the microbes which the system will contain and they don't have to compete with other organisms invading their "bacterial" space.

1.How can you provide sufficient aeration for te bacteria living in the tiny pores? 2. Is this solution scalable? Are larger scale pilots planned? (ie. treatment of 5-10 m3/d water stream) 3. Is pressure required to make the polluted water flow through the medium or you just drop it into a slow moving stream?

attilakaz

Thanks for these questions. In the lab, we keep the water aerated with stirring/shaking. Since there's typically a much larger volume of water than gel, there's a plethora of oxygen able to diffuse in. Our system is very scalable. The reagents we use can be purchased by the barrel at relatively low cost. The main difficulty in scale up would be growing the bacteria at a reasonable pace/cost. We don't currently have any pilots planned, but if the right situation presented itself, we may consider it. Our system would be best suited for a flow through reactor, where we have full control over aeration, flow rate, etc., but it could also be used in a stream. There is no flow in the pores of our gel, only diffusion. The pores are far too small.

Greetings, one of the biggest challenges that I see with the biotechnology solutions I hear about are the scale they work at. As a future ecosystem engineer I look at the problems we are facing today and wonder: what is the most comprehensive and resilient solution to this issue (yours in particular).

With my preface in mind my question is this: can this be scaled up to levels where the effectiveness meets what is needed and the costs are justified? If yes, how do you picture your technology interacts within the big picture of solutions to this problem?

Efriminiz

We think our system is very scalable. The chemicals we use can be bought by the barrel. The main difficulty in scale up would be growing the bacteria at a reasonable pace/cost. A major issue with bioremediation in general is that there's not a big monetary incentive for companies to clean things up, short of regulation by EPA or litigation by another party affected. Our technology is best suited for treating specific chemicals and is not an across the board solution. Therefore, it needs to be used as a supplement to existing technologies, not a replacement.

This is very interesting! Is it possible to encapsulate a lot of variations of bacteria? I have completed quite a bit of research on microbial fuel cells and I'm interested if this silica gel would have potential in one? I think it would be difficult moving an electron through the silica gel.

axxokiller

Thanks for your question. There's really no theoretical limit to which bacteria one could encapsulate. I don't know very much about what your requirements are for a microbial fuel cell, but silica is an insulator, so it doesn't strike me as an ideal choice. I did find this paper in which the authors used vapor deposition of silica in their microbial fuel cell. I would suspect that adding conductive filaments to the gel may circumvent this issue.

Is this method of cleaning water a relatively new process? If so, is this the next 'Brita' of water filtering?

dfish93

Great questions. Yes and no. Microbes have been biodegrading small amounts of hydrocarbons for millions of years. What we're doing now is isolating bacteria of interest, growing them in the lab, and concentrating them within our silica gel. Unfortunately, while very important for human health and the environment, this is not the next Brita. Activated carbon, which is what's in a Brita filter, adsorbs (sticks to the surface) chemicals indiscriminately. In combination with it's extremely high specific surface area (surface area per mass or volume) of around 500 m^2 /g, it's really good at removing things, with no preference for certain chemicals. However, in our case, we choose bacteria for a specific purpose, so that they can biodegrade a chemical of interest. An analogy would be a bulldozer vs a scalpel.

Hello Mr. Sakkos. Thank you for doing this AMA.

how does your material compare to a traditional plug flow reactor using the same organisms. What are the advantages of your material?

As a small side note I am currently studying environmental engineering so I greatly look forward to reading all of your answers in the thread.

Try0again0bragg

Thanks for this question. Think of the silica gel as a reactor media. I'm copying my answer from a previous question:

"Keeping the bacteria contained has multiple benefits that are not immediately obvious. First, we can contain them where we have a chemical of interest, so that we aren't losing biomass as our system continues to operate. Second, silica protects the cells from external predators due to the extremely small pores, which are typically on the order of 10 nm. That's too small for most harmful things (other microbes, bacteriophages, etc.) to pass through. Lastly, we can control the system to make it extremely efficient and utilize our bacteria fully. In a system which relies on biofilms, this is not the case."

Hi Jonathan! I'm a mechanical engineering student, second year, and I'm considering tacking on a double major or a minor in Chemistry.

What insight can you offer future ME majors considering working in life sciences?

mavambvb

I highly encourage ME majors to diversify themselves. These days, no field is really separate from the rest, everything is interdisciplinary. Take some introductory courses in molecular/cell biology, organic chemistry, and biomaterials. While your ME degree will give you the critical thinking skills required to be an engineer, you'll still need some background in whatever secondary field you end up in. Good luck!

Do you foresee any in-situ applications for this to treat contaminated groundwater?

eyeplaywithdirt

Thanks for the question. As I said in another comment, fracking waste is a huge contemporary issue that I think our encapsulation system could help treat.

Would this technology be viable for oil spill containment either on the surface of water from a crashed ship or on the deep sea from a well blowout (e.g. Deepwater Horizon)? Or is the scope of something like that much too large for realistic production and implementation?

shiruken

Great question. This technology wouldn't be able to help contain an oil spill, but could be used to treat it. Our system is extremely scalable but the main limitation would likely be how fast the bacteria could be grown to meet the need.

The abstract for your paper says that the biodegradation rate was sustained for a month before falling below 20%. What exactly is the process for "restocking" the bacteria or does it simply require replacement of the entire encapsulation unit? What can be done to increase the longevity of the bacteria?

shiruken

Great question. Once the gel is formed, the bacteria are physically confined: there is no restocking. This means that our bacteria cannot leave but also that other microbes/predators cannot infiltrate, which could jeopardize our whole system. The silica gel is typically made into microspheres, which you can think of like a biological filtration media. If the media stops working, you'd need to replace it all. We're not exactly sure why they stop working, but we hypothesized that they may not be able to synthesize new proteins while encapsulated, since they cannot move or divide. We're working on another system in which we have microscopic capsules about 50 times bigger than the cells. In this scenario, the cells can move and divide, much like they would normally, however with a physical silica barrier keeping them within the capsule.

What scientific method do you propose to eliminate the slime bacteria known as pitino from our local environment?

bass6baritone

This is a bit too far outside my realm of expertise to speculate, but thanks for the question.

Interesting stuff. Looks like you've been working a lot on the reaction conditions for optimizing the physical properties of the hydrogel. Have you looked at the possibility of using similar techniques to develop something that could be applied to a microbial fuel cell electrode?

Molecularpimpin

The physical properties of the silica gel are very important to us. No one wants a filter that gets crushed into oblivion. We've done a lot of work to ensure that our gel is strong enough for use in real-world scenarios. I'm not sure if silica is a good fit for a microbial fuel cell, since it's non-conductive. However, I know that some groups have added conductive elements (carbon nanotubes) to silica gels, which may solve this issue.

Is this kind of technology effectively a filtration system where the filter cleans itself?

krisp9751

In some ways, yes. The bacteria biodegrade the pollutants, with the (ideal) end result being destruction of the pollutant. In contrast, most traditional filtration systems remove pollutants by concentrating them. For example, activated carbon might remove chemicals from water, but you'd still need to deal with the chemicals left in the carbon.

A huge potential application for this to treat contaminated groundwater?

hair_dye462

Yes, this technology could be used to treat contaminated groundwater. Since it's extremely specific, we'd need to know the exact pollutants to choose bacteria which can biodegrade the them.

What do you think about the new bacteria that can eat plastic? Do you think it'll be able to make a difference in our lifetime's?

Rewire__Me

Great question. It's very exciting to see that there are bacteria which can eat plastic. Given enough time, bacteria will evolve to eat just about anything containing carbon. That being said, I'm not sure if the rate at which they can do so will be fast enough to deal with the volume of waste we produce. A better solution, in my opinion, is to switch to biodegradable polymers, so that we can ensure that plastic in the environment doesn't persist for thousands of years.

Can filter be used to remove Americum from radioactive discharge, or is the particle too small?

lavendula13

I'm not sure that bacteria can biodegrade Americum, but there are bacteria which can survive in radioactive environments.