Science AMA Series: In India clean water is a luxury—more than 250 million people drink untreated water. We think we have a solution, We are MIT Professor Amos Winter and PhD Candidate Natasha Wright. AMA!

MIT$_{C}lean_{W}ater^{1}andr/ScienceAMAs^{1}$

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April 17, 2023

Abstract

Unfortunately, that's all the time we have to answer your questions today. Thanks to everyone for your fantastic questions! Follow @MIT_alumni, @MITMeche, #MITBetterWorld to continue to get news around our work. +++++++++++++++++ In India, roughly 45 percent of the population is drinking untreated water. In the rural village of Mhasawad, many residents regularly drink water with salinity levels of 1,200 ppm (parts per million), double the levels recommended by the World Health Organization. Water with high salinity levels can cause countless health problems including kidney stones and digestive problems, and taxes the energy grid. But for many, purchasing treated water can cost upwards of 30 percent of one's monthly salary. At the beginning of this year, we traveled to several rural villages to meet with farmers and villagers to better understand the problem. Back at MIT, we are now developing a cost-effective solar-powered desalination system to provide a safe and affordable source of drinking water. This is not just an engineering problem—we are operating as product designers, ethnographers, social scientists, and machine designers to test our assumptions and build a lasting solution. Ask us anything! Watch the recent video "Water is Life" on our work: https://www.youtube.com/watch?v=lLPiIChFMIA Read the recent article "A Quest for Clean Water" published on MIT News: http://news.mit.edu/2016/solar-powered-desalination-clean-water-india-0718 ABOUT US: Amos Winter: I'm an assistant professor in the Department of Mechanical Engineering at MIT as well as an alumnus of MIT. I also am the director of the Global Engineering and Research (GEAR) Lab, which focuses on the marriage of mechanical design theory and user-centered product design to create simple, elegant technological solutions for use in highly constrained environments. Natasha Wright: I'm a doctoral candidate in the Department of Mechanical Engineering at MIT, a Fellow in the Tata Center for Technology and Design, and an alumna of MIT. My current work focuses on using electrodialysis technology, powered by photovoltaics, to provide clean drinking water in off-grid settings.

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MIT_CLEAN_WATER R/SCIENCE

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WRITE A REVIEW

CORRESPONDENCE:

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How are you developing a project that can be sustainable beyond your presence in the communities? In other words, what happens when parts break? Also, are you developing water filtration systems that handle other water purity issues such as those which come from open defecation or is it just for salinity?

firedrops

Hello! This is Natasha, thank you for your question. Sustainability from an economic, environmental, and technical perspective are all very important. The first thing that we have tried to do is to work with existing companies in the water sector, that already have channels available for maintenance and service. For example, right now we are working with (and our research is funded by) Tata Projects in Hyderabad. They already have ~2000 village scale desalination plants using another technology in the

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field and a network for service and maintenance (field technicians, a 24 hour hotlines, etc). The second answer to this question is that we are trying really hard to understand the optimal operation plan for the system on a day-to-day basis. So for example, we can make the system fully automated so all you have to do is push "go". Or, we can use a manual valves, manual instrumentation, that would reduce cost but require human reliability. In our first field trial, we actually got a lot of feedback requesting a less automated system...they wanted manual ball valves for example that are less likely to break and not concerned about the idea of having someone there to operate the plant throughout the day. I spend time in India 2-3 times a year interacting with communities and existing organizations to try to understand what will work best from this prospective.

The current system we are working with uses electrodialysis to remove dissolved salts (an charged particle... you can think of sodium and chloride, but also things like fluoride). To remove the biological contaminants we use UV disinfection. So, while we can deal with the issues that come up from open defecation (biological contaminants), it wouldn't really make sense to use our system unless you also had issues with salinity.

How helpful has the Indian Government been during your interactions with the officials.

Is this done by your team only or is it a joint effort by you guys and the Indian Government.

How widespread do you expect this technological advancement to be. Do you think all of India will drink water treated by your system? What about the developed countries?

black-clothes-saul

This is Amos: We haven't yet involved the national government, but we regularly meet with local government officials when doing field work. We also interact a lot with other organizations that work with the government, that understand subsidies and other factors that are relevant to disseminating the technology. For example, Tata Projects (one of our funders) already runs a business of making RO systems for villages on the electrical grid. They work with the government to implement systems and understand many of the nuances of making those projects successful.

We expect our technology to be applicable to many areas in the world. Concurrently with our work in India, we are setting up a pilot of our tech in Gaza with UNICEF and USAID, which should go online at the end of the year. Our system desalinates brackish groundwater, which is more prevalent around the world than fresh groundwater. Our tech is particularly appropriate where there is not reliable grid electricity access, such in rural villages in India, and arid regions that do not have reliable infrastructure like Gaza.

We are also beginning a project that will look at the application of our technology to arid regions of wealthier countries, like the Southwest U.S. This work will be funding by the Bureau of Reclamation. Our tech would be particularly appropriate for remote areas, or those that want to promote green energy through solar power. In the future, we hope to design versions of our systems that are lightweight and have minimal batteries, so they can be air-shipped for disaster response.

Is your desalination method restricted to mildly brackish water, or can it be used on seawater, with the same cost-effectiveness?

weaselword

This is Natasha : Electrodialysis can be used on seawater, however it requires more energy (and thus more cost) than what is required for less salty brackish water. For that reason we are focused on groundwater desalination.

Thank you for this AMA and your work is an awesome example of progress for humanity.

Does your system have a limit to salinity it can handle? Would this be able to desalinate ocean water (approx. 30x the salinity)?

Also, what kind of production volume does one unit have; enough to support a family, a village, a small town? Thanks!

adamdj96

This is Amos:

Thanks for the kind words!

Our system is most appropriate for brackish groundwater. The sweet spot is around 1,500-3,000 ppm of total dissolved salts (TDS). To put that in comparison, seawater is around 35,000 ppm.

Our target system size would produce about 10,000 L of water per day, which would be enough to provide drinking water for a village of about 3,000 people. We are not limited to this size though. We are developing the engineering theory to make our tech for many size scales and applications. Eventually we will be able to tell you what size and architecture system you would need given your location on the earth (for solar power), groundwater salinity, and how much water you want to produce per day. My research group is also working on much smaller scale electrodialysis (ED) desalination systems, which would be used in homes. The advantage we see there is that ED can reduce water wastage to ~ 10%, whereas current RO home use systems waste 60-80%.

As an Indian,Thanks for what you're doing and for making millions of lives better.

And my questions are

- What exactly was the situation you saw when you were here in India? Can you elaborate a little?
- As an Indian with access to clean drinking water,How can I help make sure others get access to it too?
- What exactly is the process by which clean water is created?
- And did the trip to India and seeing the situation affect your lives in any way?

Thanks and all the best for your future endeavours. I will be following this closely and doing my best to help get more people access to clean water

AwkwardIndian

This is Natasha. Thank you for your question!

My first trip to India was in August of 2012. I had just started the project and was mostly focused on biological water contamination because that is what is talked about the most - biological contamination like bacteria and viruses are what cause diarrhea and much of the childhood death. However, when I went to visit communities and started doing interviews, I found that many people had access to home water filters for treatment of biological contaminants, but weren't using it. When I asked why, they told me that the filter they had didn't make the water better...by that they meant they couldn't tell it was better (it didn't taste better, smell better, or look better). They started to tell me about how salty their water tastes, and how this makes them have stomach aches and causes kidney stones. I then started to do the research back at MIT to find that 60% of the land area of India has water that is too salty to drink or use for agriculture...which is when we started focusing on desalination.

One of the biggest things you can do right now is be aware of the issues surrounding water scarcity in India. Many of the home use system used in urban areas waste 60-70% of the input water.

The desalination process we use is electrodialysis. Salt is removed through the application of a voltage potential. The negative and positives ions (like chloride and sodium) are attracted to the two electrodes, but separated by a series of membranes. Check out this short video description: https://www.youtube.com/watch?v=wYkkLUckmg4 We treat for biological contamination using UV disinfection.

I love the research I am doing and am motivated every day to continue because of the time I have spent in country. Context both motivates and dictates the design decisions that I make.

About every 3 months I see another article / TV spot about someone who has invented another way to purify water for next to free --- but these inventions all seem to disappear and nothing comes of it.

I wonder why.

Arizona-Willie

This is Amos:

I really appreciate your comment. I too am frustrated by flash-in-the-pan innovations that will never see the light of day.

What we have tried to do in this project is balance the socioeconomic factors that will make our technology viable for the market, with the technical innovations required to get it there. This project started with two years of detective work to understand what the most common water contaminants are in India, who the affect, how many people are affected, where these populations live, what power sources they have, and how much they could pay for clean water. What came out of this study is that off-grid desalination technology could benefit hundreds of millions of people in India, and many more in other areas of the world with brackish water. You can read about this study here: http://gear.mit.edu/Publications/Desal/IDAWC15_Wright_Final.pdf

We also learned that Reverse Osmosis (RO) is difficult to take off the grid in India because of the cost associated with the required solar power system, which would actually be more than the RO system itself. Electrodialysis (ED) has a big advantage here, because it requires half the energy as RO for the salinities you commonly find in India. The other big advantage of ED is that it wastes only about 5-10% of input water, rather than RO at village scales which wastes 40-60%.

Our partner Tata Projects taught us about the price point we would have to hit for our technology to be economically viable. They know this because of the on-grid RO systems they sell, which have been shown to cover both the capital and recurring costs through sales of water. This price point is about $10,000 for a 10,000 L/day system. We are trying to hit this price point with an OFF-GRID ED system. The big cost savings comes largely from reducing the required energy (and solar power system costs). Through our research we have seen there are other ways to lower costs by lowering pumping energy and creating new configurations of the ED subsystem. We are seeing that even with existing versions of ED manufactured at scale by our partners, we should be able to come very close to the price point of current on-grid RO with off-grid ED.

So in summary, we have tried to be diligent about accounting for all of the socioeconomic and technical factors that will determine if our tech can be disseminated. We are constantly learning and adapting, and that is why we are doing field trials. We are also partnering with Tata Projects, which knows the rural water desal market and can manufacture and distribute products based on our tech at a large scale.

India spends 6th largest amount on military and has the 7th largest GDP - third largest in purchasing power.

My question is: isn't the solution rather simple? Does it really require highly educated non-citizens to solve India's water problem? Can't they just invest in sanitation infrastructure and clean up their factories? Does India really need outside influence to solve this problem?

Sonmi-452

This is Amos:

The communities we are trying to target are 2000-5000 people, which make up 1/4 of India's population. These villages typically have brackish groundwater do not have reliable grid access (either not connected, or not on for the duration of time to desalinate water).

For villages that are on the grid, our partner Tata Projects has already been successful selling RO systems. They have done about 2000 throughout India, have shown that they are economically viable.

If you try to take one of these RO systems off the grid, the capital cost more than doubles because of the solar power system cost. This makes the technology infeasible.

Even though electrodialysis (ED) requires much less energy, the technology as it stands today is not ready for these off-grid applications. Most commercially available systems are much bigger than what we need, and are thus too expensive. And most have been designed to run on grid power, which with a reliable grid can deliver a constant level of power 24/7. Our power source is solar, which has variable power that changes through the day and year. Imposing this power constraint on the design of a system drastically changes the optimal configuration you would want. We are researching how to make optimal systems given their location in the world (and weather), groundwater salinity, and how much water needs to be produced per day. This is a tricky problem - one that we feel warrants the involvement of highly educated non-citizens :)

Thanks for participating in an AMA.

What materials realistically could be implemented to increase efficiency or simplify the process if they are modified or costs are decreased?

From a (nano - micron) materials chemist's standpoint, cost is the major barrier. However engineers and material scientists are/have greatly lowered the cost of generating base materials that have significant performance (2-D layered materials, nanocolloids, etc.).

BlackManonFIRE

This is Amos:

GE water recently came out with carbon electrodes for their electrodialysis (ED) systems, which should be much cheaper than the platinum coated titanium electrodes that are used currently. We see this material change as a big cost savings. We have started building little test versions of these electrodes and will be characterizing them.

My group won't be working on new membrane materials for ED systems. The membranes allow ions be separated out of the water. Since my group focuses on machine and product design, membrane design is out of our wheelhouse.

What we are working with a lot of effort is new architectures for ED systems. The way the electrodes and membranes are configured has a big impact on their cost and how much power they require. We are also investigating how to reduce pumping power losses. These may not be a big deal for on-grid systems, but when you go off grid every big of energy is more expensive. The energy we have to put towards pumping can consume anywhere from 30-80% of our budget.

We have also seen that we may be able to significantly reduce cost by better optimizing the sizing and interaction between the ED and solar power subsystems. This is a very active area of research for my group.

Nano filtration could make sense as a pre-filtration for our system, but we are currently not working with this technology.

Hi, thank you for doing this AMA. In our village in India (Himachal Pradesh at 7500-8000ft) we get untreated spring water, we use a tap based filer that takes out most of the silt and a 4 stage gravity filer like this. As you pointed out, the local population gets a lot of kidney stones as well. Is this much filtration enough to prevent kidney stone formations?

To use the water as boiler feed in a small factory we had the water tested a litter earlier, we got the tap water and the natural spring water tested, and we are using a softener for the boiler feed.

As for drinking water, based on these tests, whats the optimal solution to get safe drinking water according to you?

Will solar desalination work in hilly terrain where we mostly have small springs as source, and what would an indicative cost be to desalinate water for say 500 households. Thank you!

kartoos

This is Natasha. Thank you for your question! I'm sorry to hear that your community is struggling with safe water sources, although it sounds like you have been very proactive in finding appropriate solutions. From what I can tell in your spring water tests, all of your dissolved ions (chloride, hardness, etc.) is within the limits for safe drinking water so you would just want to make sure to do a treatment for potential biological contamination which is not shown in that report. Simple chlorination is always an option, UV disinfection is low energy and very effective. If the amount of salt that is in the water is troublesome from an aesthetic perspective, you could look at desal but it doesn't look like that will be needed from what you've shown me here. Feel free to email me if you have more followup questions.

You say you're "operating as product designers, ethnographers, social scientists, and machine designers." How's that balance been? As engineers, how are you approaching the social sciences aspect? Have you consulted with social scientists?

recentfish

This is Amos:

Great question! I can't stress strongly enough how important our socioeconomic work is and how profoundly it affects our technical decisions. Time and again we will think we have things figured out, only to go to the field and understand a new perspective that changes what we engineer. For example, our first Indian pilot electrodialysis system was automated. When we brought farmers in to interact with it, they stressed they wanted as simple a system as possible so it would be easier to repair in the village. This made us decide to make a manually operated system for our next Indian pilot, which will be launched at the end of this year.

To be honest, I always feel that we should work more with social scientists. We very much try to implement good social science techniques when designing our surveys, and my students take classes on these techniques. I also teach about ethnographic research in my graduate course on emerging market technology design.

Here are parts of the strategy that I think have served us well. 1) We always recognize at the beginning of a project that our contextual knowledge around the problem is very limited. This forces us to reach out and form partnerships with companies and orgs that really know the market we are trying to engage. This is why we work with Tata Projects, Jain Irrigation, USAID, and UNICEF on this project. This also makes us really reflect on what our core competencies are in the project, which usually revolve around engineering, research and innovation. 2) We go to the field every few months. Me and my students are constantly trying to connect with many different types of stakeholders who will influence the success of a project. These are companies, governments, NGOs, and of course end users. 3) We try to fail early and often. We take prototypes to the field and get feedback as much as possible. We know the pilots we are running now are not going to be perfect, but we will learn a lot and make mistakes now that we can avoid when we scale up for commercialization.

Thanks for doing this!

In the future - how do you see this progressing? Specifically, do you see this as being a "personal unit" for each person? Or do you see this more the traditional large water filtering station, with full time employees

It would seem the former would allow them to "take control" of their water suppy sooner...

USModerate

This is Natasha, thanks for your question! I am working on village-scale systems, potable water for 2000-5000 people villages (6-15 cubic meters per day). At the price point affordable for many of these communities, village scale makes more sense... the price per liter is much smaller, with a single operator we can ensure that operation and maintenance is happening correctly. However, there is also a large market for home-scale systems, especially in the urban market. We have recently started a branch of our research to focus on this aspect.

Regarding the energy storage, from the article:

Currently, the solar panels are equipped with batteries to store extra solar power and distribute it evenly throughout the day, but they are investigating alternative designs that may allow the solar panels to connect directly to the EDR stack while maintaining a steady distribution of power throughout 24 hours.

What kind of batteries? What capacity? Alternative designs? Like, mechancical backup alternatives?

AgentCoffee

Hello, this is Natasha. Thank you for your question. With solar power, in order to produce the same amount of water each day you need some sort of storage, one example is batteries (which is what we are currently using - VRLA batteries to be specific) but you can also think of water storage. We are currently looking at the optimal configuration of panels + water tanks + batteries.

What are your plans and infrastructure to promote the longevity of the results of this project? It's awesome of you to do this, but how are you going to ensure this won't end up being like many other aid projects that essentially get dropped off, checked up on once or twice then disappear from the face of the planet?

Have you considered utilizing local charities or groups on the ground in India to help motivate and increase community involvement/education about this project?

And why just out of curiosity, why India?

sarawras

Hello, this is Natasha, thank you for your question! I answered most of the question above (we work with a number of companies and NGOs on the ground to strive towards sustainability).

In India over 60% of the land has groundwater that is too salty to use for potable or agricultural use. The large majority of the rural population uses groundwater (not surface water), thus the water solutions are different than what you might find in other regions where surface water is the primary drinking water source.

In addition to desalination - defluorination, biocidal treatment is also one of the things that might be needed in India. Is there a subsequent follow-up to your particular way of purification? Also, who funds this - the government or PPPs?

have_free_phone_con

Electrodialysis removes any charged particles, be it dissolved salts like sodium and chloride, or certain heavy metals, like fluoride. We also use UV disinfection for biological contaminants. Depending on what else is in the water (pesticides? herbicides?) we can add additional modules. We are funded by the Tata Center for Technology and Design at MIT, Tata Projects, Jain Irrigation, UNICEF, USAID, and NSF.

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We use UV disinfection to remove biological contaminants (bacteria, viruses, protozoa)... thus the UV has a similar role as boiling water would have. Boiling water however does not remove salt. We add on another tech called electrodialysis to do the salt removal.

When a product is to be used by poor villagers, the design of the system obviously needs to be easy to comprehend and operate. What all criteria did you keep in mind while designing such a system? How easy will it be for them to use? Sorry if this is a silly question.

Thanks Dr.Winter and Dr.Wright!

windowrain

Hello, this is Natasha. Thank you for your question, it is not at all silly! I touched on this question a little in the above answers.

The first thing to consider is that there are a number village desalination plants across India that have been installed by Tata Projects (the company we work with) that have been operating successfully for a number of years. So, I spend time at those plants, speaking with their operators, understanding what makes the system easy to operate and what the most challenging aspects are. I talk to the village head to understand how the operator was chosen, and what educational background they might have. While desalination systems of any kind have a number of parts and do require some maintenance, much of that maintenance is pretty easy to teach: "to change the filter you remove this housing..." , "to check the salinity do this". Generally speaking operators are given things to look out for (if this reading gets to high, if this is leaking) and then given a list of things to do if that happens.

Okay so that is how the operator is trained, but how do we make it easy to begin with? Well we talk to communities about what "easy" means... you might think that a fully automated system is the easiest, you just hit a button and it starts! However, automated systems generally have a control box, wires, electric valves, etc. that can break... especially if they are low cost and in a wet, hot environment. When we spoke to users we found that they would actually prefer a more basic system (manual ball valves instead of electric valves for example) that are less likely to break, even though it would require more steps in the day-to-day operation.

Was there a specific reason as to why India was chosen at your focus?

Do you have plans to expand your efforts to other water-stressed areas of the world or will you be focusing on India, specifically, for the foreseeable future?

DirectlyDisturbed

Brackish groundwater underlies 60% of the land area of India and the large majority of rural communities use groundwater as their primary drinking water source. This is different than many regions of the world where surface water sources are more prevalent.

We are currently working on a pilot plant that will be installed in Gaza later this year... so yes! we are definitely looking to expand into other water-stressed areas of the world.