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Sandia National Laboratories

Susan Murcott,

MIT

Judith Barry,

Alliance to Save Energy

Jim Phene,

Netafim

Moderators

Peter Davies,

Sandia National Laboratories

***Erik Peterson**,*
CSIS

Center for Strategic and International Studies

Tuesday, March 8, 2005

Panel One:
Available and Future Technologies

Erik Peterson: If we could ask you to take your seats, we're ready to start the first panel discussion.

As I mentioned in my opening comments, our first panel today is going to focus on looking at technology from the standpoint of where are we today and where might we be at some point in the future and we have a very broad cross-section of expertise on this panel. We will follow the same overall format that we used in the first workshop which is to have a series of brief presentations by each member of the panel followed by an open discussion, open to the floor as well as to other panelists, to explore some of the broader questions that we're looking at in this panel as well as to understand in more detail comments and insights from each of the panelists.

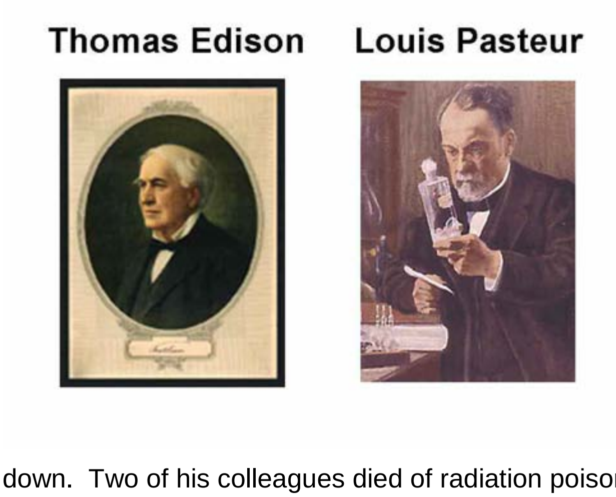
In terms of order, we will follow the order that's in the agenda. Let me introduce our first panelist.

Tom Hinkebein is the manager of the Geochemistry Department at Sandia National Laboratories where he is responsible for a number of fundamental science studies as well as responsible for water treatment activities. Tom received his PhD in chemical engineering from the University of Washington in Seattle and has been at Sandia for 25 years. In the novel technology area Tom and a group that he is working with are looking at arsenic removal, perchlorate removal technologies as well as desalination.

The last comment I would make about Tom is that he was the technical lead for an effort that was a collaboration between Sandia and the Bureau of Reclamation in the Department of Interior to create a desalination/water purification technology road map which is this document that I have here. I know that Tom has a number of copies of this document with him and there are also copies of this document available on the web in pdf form.

So I'd like to welcome Tom and we look forward to your comments.

Tom Hinkebein: I'm going to begin this discussion by contrasting two very famous scientists -- Thomas Edison and Louis Pasteur.



Thomas Edison had a slogan that scientific discovery was one percent inspiration and 99 percent perspiration. The development of the practical light bulb, Edison tested over 3,000 filaments, if you can fathom that. Indeed, his methods were incredibly successful as he developed over 1,093 patents during his long and successful career. His discoveries were characterized by the use of trial and error.

In his studies of radium, however, the trial and error approach let Edison down. Two of his colleagues died of radiation poisoning and Edison himself lost all of his hair from radiation sickness.

In contrast, Louis Pasteur said in the field of observation, chance favors the prepared mind. Louis Pasteur was conducting fundamental studies on the origins of life when he

discovered that heating bacteria to temperatures over 140 degrees would cause bacteria to be inactivated. This was a problem for his original experiments because his purpose was trying to keep bacteriological strains alive. However, through his knowledge of the needs of the world he realized the value of inactivating spoilage mechanisms to a most precious drink -- wine. [Laughter]. Pasteurization was later applied to milk and other foods.

However trial and error was essential to the development of scientific methods. Early in our discovery the greatest advances were a combination of inspiration and good luck.

Modern scientific advance must avail itself of knowledge gained by our predecessors. In fact understanding the basic scientific principles allows us to plan research and to guide our exploration. It further allows us to estimate the boundaries of potential gains.

For these reasons some of the potential advances that I will discuss in this presentation are speculative. However, forecast gains are realistic and achievable. The case studies that I am going to present are not intended to be exhaustive but are rather intended to be inspirational.

Pasteur's statement was never truer. There are no such things as applied sciences, only applications of science.

So what's the goal of water treatment? In the road map we come up with four characteristics -- making water safe, sustainable, adequate, and economical for this and future generations.

In the membrane treatment of water we are currently making membranes with a range of pore sizes, the loosest of which filter bacteria and viruses out of drinking water. Those microfiltration membranes are experiencing increasing use worldwide and currently are experiencing market growth that we typically expect in the electronics and pharmaceuticals industries.

At the other end of the spectrum, membranes have dimensions which approach molecular size. These membranes are referred to as reverse osmosis membranes and they successfully separate salts from water. For this type of filtration the continuum model of water no longer applies. Pore sizes for these membranes are now at molecular dimensions. The molecular structure of water is important within these membranes. Indeed, the polar nature of water itself, or hydrogen bonding, provides major limitation to passing water through an RO membrane. This is so because water molecules must pass single file through reverse osmosis membranes.

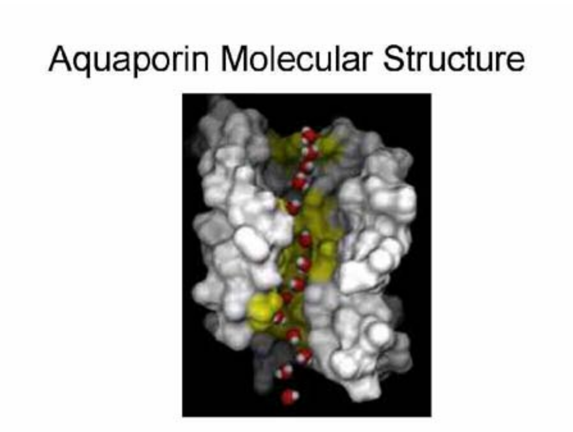
Imagine trying to exit a basketball arena -- my favorite sport -- in which everyone links arms as they try to exist. Hydrogen bonding acts much the same way. It's not surprising that extremely large pressure are required to successfully pump water through RO membranes.

In reverse osmosis the next goal is to overcome hydrogen bonding in our quest to reduce energy use in membrane treatment. The water/salt separation process must break many hydrogen ions between adjacent water molecules to allow them to pass through a pore in single file.

The process of breaking these bonds requires a great amount of energy -- translate that to pressure. This results in thermodynamic efficiencies that are five-fold greater than the thermodynamic minimums for the best available membranes of today.

In 2003 Peter Agre of John Hopkins University received the Nobel Prize in Chemistry for elucidating the structure of aquaporin. Aquaporin is the water channel that separates salt and

water in the human kidneys. The aquaporin structure is the key that unlocks hydrogen bond structure of water. It is perfectly configured so that water naturally aligns along its structure, in effect neutralizing water/water bonding.

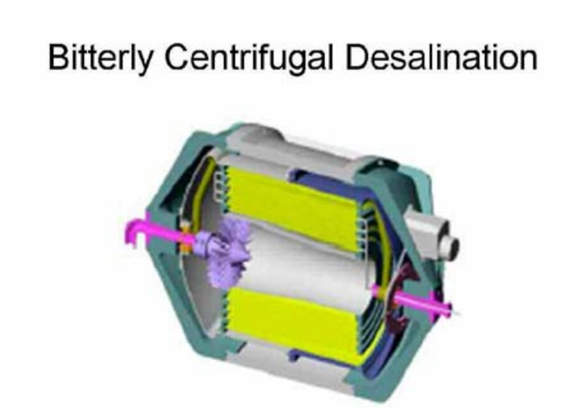


The water channel operates at fluxes that are ten-fold greater than are obtained in synthetic membranes. We believe that the aquaporin structure is an important key to efficient water transfer.

We further believe that either it can be made synthetically or naturally occurring aquaporin can be grafted into synthetic polymers to allow water molecules to walk single file through the water channel.

In our belief, aquaporin is the next generation membrane structure that may allow us to finally approach the thermodynamic minimum. If this is successful, huge energy gains, by that I mean 50 to 80 percent over current technology, will be possible.

In our quest for zero energy use in water treatment, a breakthrough in a totally different area may allow us to get there. In the 1970s when NASA was just beginning to consider a manned mission to Mars, Jack Bitterly was developing bearings that would allow flywheels to turn at great speeds with very little energy. Jack holds several patents on these devices and conceived of one that may revolutionize water purification. We currently know that large thermal separation devices function with huge losses because the liquid films in these devices are governed by the influences of gravity. Highly efficient heat transfer requires very thin films.



Bitterly conceived and built a machine that puts water films in these high gravity centrifugal fields. He further drew a vacuum on the device so that evaporation and condensation happen at naturally occurring ambient temperatures. In essence, he does not add heat to this thermal device. It functions at very close to atmospheric. Further, the films are so thin that highly efficient heat transfer takes place many-fold better than occurs in other thermal devices. The water produced from this device is free of bacteria, viruses, and salt, and the temperature of the output water is only different from the input temperature by several tenths of a degree.

Evaluation will tell us if this next generation water purification device actually measures up.

Not all of the improvements take place at large scale. It's well known that energy recovery is about as good as they can currently get. They have 97 percent plus efficiencies. A huge amount of effort to improve these systems would be misplaced or wasted. However, the need for point of use devices is still very high.

The home reverse osmosis unit that you can buy at Home Depot is only about 20 to 30 percent efficient. This means that you throw away 80 percent of the water as waste while getting a pristine stream with the remaining 20 percent. This is so because these systems do not operate at high enough pressure to employ pressure recovery systems. In an environment where water supply is boundless, this is an acceptable solution. Of greater interest is how to produce fresh water by sipping from our precious resources.

The Spectra watermaker provides input into this arena and the Spectra system high pressure operation with well-known recovery principles opens the possibility of 60 percent recovery with existing technology.

I'm going to ask you, if you would, Laura, to tap on arrow and activate the movie.

With subsequent staging -- What this device does is it uses the discharge pressure from your membrane to push the pistons in the opposite direction, so it ends up providing a mode of pressure to the input stream and increases the efficiency in a point of use device, something that has typically not been done.

With subsequent staging as is done in largescale systems, 85 percent recovery should be possible with this point of use device.

In commercial scale reverse osmosis devices the reject stream typically contains 95 percent of the pressure that was put into the system. So this is a very attractive process for allowing us to have point of use devices that are highly energy efficient.

Another area where improvements are possible is in the control of waste streams. Standard water treatment where chemical purification is occurring, the control of waste stream is critical to our long-term success. In the desalination and water use arena waste streams frequently contain many valuable resources.

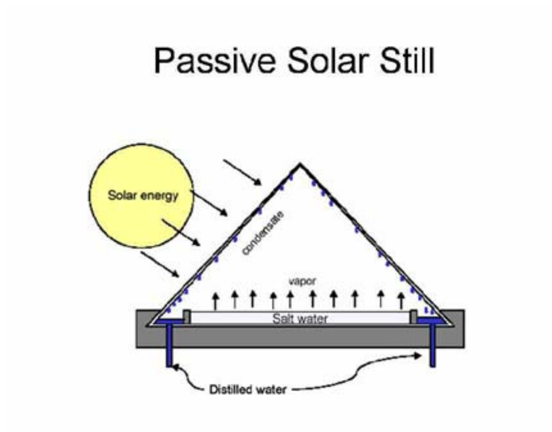
Seawater is rich in many salts. Magnesium, for instance, the third most common salt in seawater after sodium and chloride is present in .13 percent of all seawaters. This seems like a small amount, but this element is used in alloying aluminum and it's inherent value is ten-fold the cost of current desalination processes. If we can make magnesium extraction from seawater more efficient, then the cost of seawater desalination could be totally paid for by the recovered resource.

It's our belief that effort should be spent on extracting value from the waste stream.

Modern separation science is being applied to waste streams to improve and purify the value of the waste stream. This not only reduces the mass of the waste stream but also conserve resources which should make the production of water more sustainable.

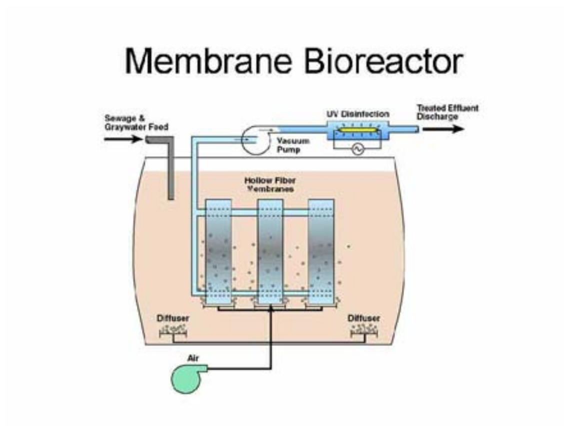
Next, simple devices need to be improved. Many areas of the world are completely separated from the electrical grid. Development of a solar still that is simple to use and repair but also solves some of the scaling and efficiency problem of their ancient predecessors is an important addition.

Solar stills are important because they naturally provide the greatest protection to the user, the combination of elevated temperature and separation of liquid and vapor phases virtually assures that no viruses or bacteria enter the treated stream.



The last area where technology is playing an important role is in the waste processing for reuse applications. The development of the membrane bio reactor is one of the central devices in this discussion. This device is a combination of modern membrane treatment and conventional aerobic wastewater treatment. Water is produced that is appropriate for many secondary uses including agriculture. The cost of the MBR is less than conventional wastewater treatment because the process footprint is greatly reduced.

In summary, there are seven points that show how technology can greatly impact water supply. First, in order to scientifically enhance water supply we believe the approach of Pasteur forms the basis for road map planning. In the field of observation, chance favors the prepared mind.



Second, in membrane development, advances in molecular dynamics and nano-science will lead the way to the next generation of highly efficient membranes.

Third, thermal separation is poised for the next great leap forward. These advances should not be ignored for many regions of the world where bacterial and viral contamination and scaling present challenges for membrane separation.

Fourth, point of use technologies represent huge potential for the cases where purity must be assured. Increasing the efficiency of these technologies will help conserve resources.

Fifth, water stream processing with the intent of discovering beneficial uses represents a fertile area for research. These improvements may well provide energy and raw material to pay for our water supply development.

Sixth, the use of simple devices for off-grid use may allow for a greater number of the world's population to have access to treated water.

Seventh, advanced wastewater treatments should be applied to reduce cost and ensure that precious water resources are re-used for essential agriculture.

In conclusion, many would argue that the need for water across the world is so great that a discussion of technological innovation is misplaced. We have adequate technology to address the need, so let's get on with it. We should use what technology we already have to fix the problem, and not invest in innovation. Research only dilutes our efforts. And yet we've had a

decade of water and brought water to over a billion people only to return to the same initial condition with a billion people still having a need for fresh water.

Consider one billion people without fresh water. How can we solve this problem? Suppose that we could get every taxpayer in the U.S. to support the initiative. My estimate is that a one-time modern infrastructure cost for the world for those billion people would cost $10,000 for each U.S. taxpayer. This is clearly too expensive and our subsequent daily costs are still not included. Further, how would we deal with the world population growth?

So what is the best approach? I believe that a sustainable solution to the problem will only come when society can adequately develop their own resources to sustain their own economy. The pyramid of development is my suggested application to Maslow's pyramid. It suggests that the first stage of need, people get enough water to meet their survival needs, basic subsistence. The second stage, improving the quality of water that they have is critical. The third stage brings the creation of infrastructure to support neighborhood and community. The fourth stage is the creation of economy. At this point I believe societies become self-sustaining.

Let me close with the following. Water treatment innovation has a millennium's old history, but great future innovation is close at hand. These innovations will dramatically reduce the cost of fresh water for the world's population. With a reduction of treatment costs, new innovation will play a vital role in bringing clean water to all of us.

Thank you very much.

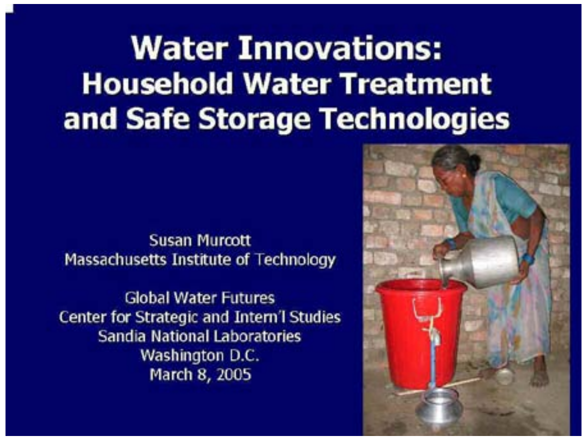
[Applause].

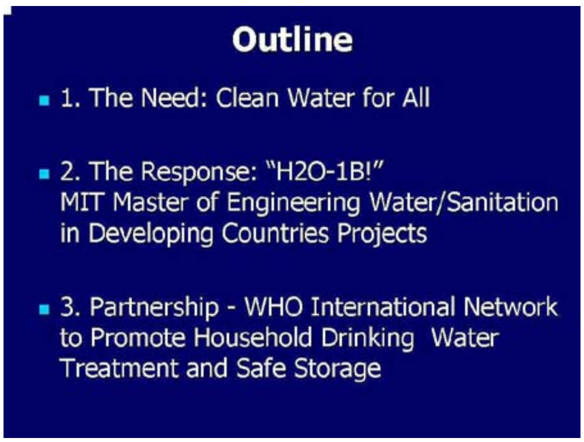
Erik Peterson: Thank you, Tom.

I'd like to invite our second panelist to the podium. Susan Murcott comes to us from the Massachusetts Institute of Technology where she is a lecturer, research engineer and principal investigator in the Department of Civil and Environmental Engineering. Her work focuses on innovative and low cost water and wastewater treatment technologies for developing countries. She has been a pioneer in the emerging field of household drinking water treatment and safe storage to reach the challenge that we have see multiple times -- one billion today, people in the world that lack access to safe drinking water, and the over two billion that lack access to adequate sanitation.

She has established a program. The program is called Clean Water for One Billion People. A very straightforward, to the point program title. There's even a little equation that comes with it. A formula. But this is a program within the Department of Civil and Environmental Engineering at MIT. It works collaboratively with other departments in taking a multidisciplinary approach including students from the Sloane Business School, Urban Studies and Policy, Mechanical Engineering, and the Harvard School of Public Health.

Susan?

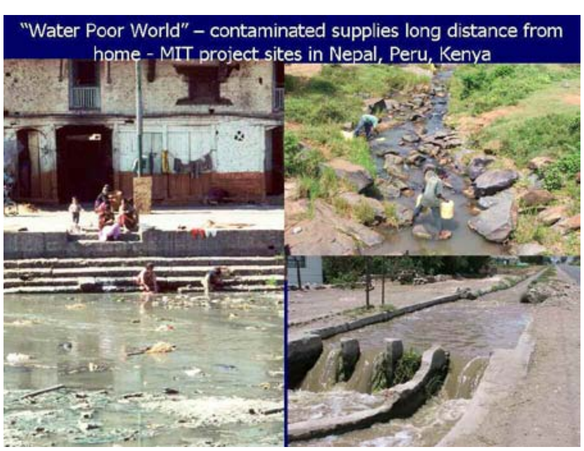




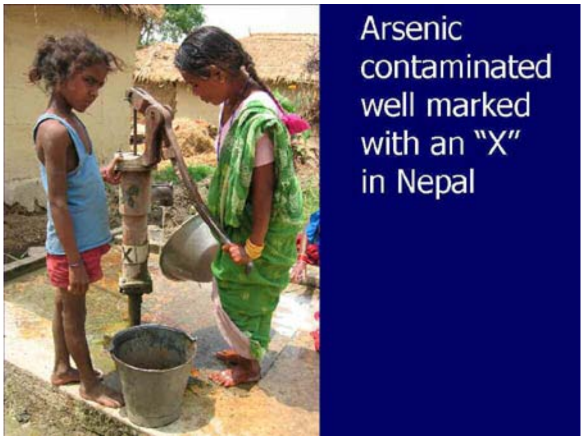
Susan Murcott: So yes, I'm going to speak about household drinking water treatment innovations and the work of myself and my students.

We all at this conference are from the water-rich world as we sit here with our bottle water and our cups of coffee, where we can expect clean water from the tap. Following a multiple barrier approach, not just for safe drinking water, microbially safe, chemically safe, but also aesthetically pleasing drinking water that could even include household filters such as this one by Brita.

I looked on the box of Brita in my lab and one of the main purposes of a Brita household water filter, which is post-tap, is to remove chlorine. It's to improve the aesthetics of the water. But the water-poor world have contaminated supplies and people have to go long distances for those supplies. This is all familiar to the folks gathered here.

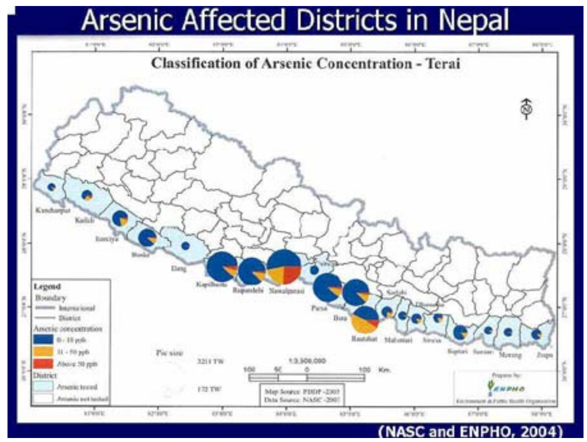


The project sites of my MIT students and myself include places like Nepal, the first photo on your left there; on the left at the bottom is Peru; and at the top Kenya, from whence I and my students have just returned. For five weeks we were there in January. So these are obviously supplies that are not something that we would want to drink.



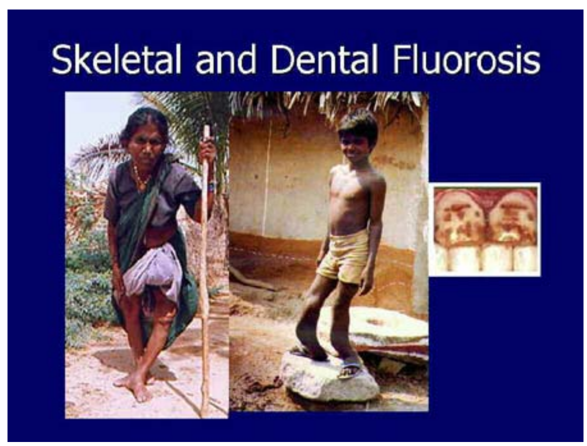
Less visible as seen in the other pictures, but still no less deadly is the arsenic contamination problems of parts of the developing world, as well as the developed world. This well has an X on it to indicate that there is arsenic present in the well and water should not be drunk from that well.

My students and I and partners have been working to map and to provide treatment solutions in Nepal, and it's in the south, in the adjacent areas to Bangladesh and West Bengal where the arsenic is occurring.

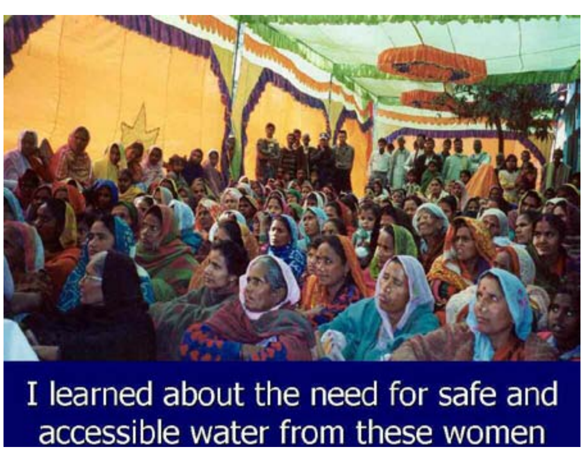


Again, this group is well familiar with the arsenic problem, but there are skin diseases, keratosis, melanosis, as well as cancers that are the effect of drinking arsenic-contaminated water.

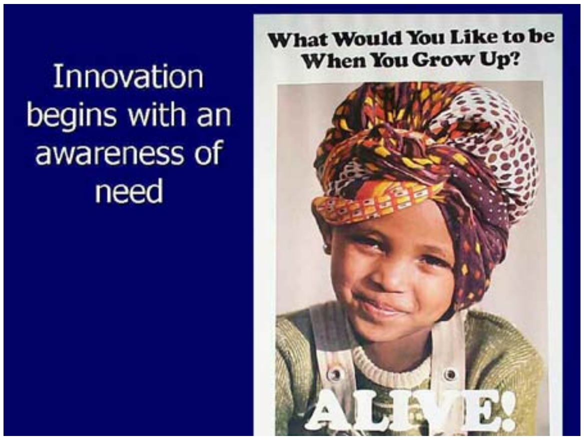
Other water-related problems that my students and I see are guinea worm contamination in Africa, and we're just beginning to work on the problem of fluoride contamination in Kenya and in the coming year I'll also be working in Ghana. Too much fluoride in the water. Obviously small amounts of fluoride are protective of your teeth, but too much fluoride causes skeletal and dental fluorosis as shown in these slides.



Having only contaminated supplies, women become the primary caretakers of children and other family members sick and dying from waterborne diseases. I learned about this need first in 1998. I'd been a water engineer for a decade or more and had done a lot of work in developing countries through the '90s with the professor that I studied with at MIT. Working on large infrastructure improvements and innovations in wastewater treatment in mega cities of the developing world. But it wasn't until 1997, 1998 that I actually had the opportunity to meet face to face the people, mainly the women, who are impacted by these water problems. This took me down a kind of different path, which is what I will be describing further today.

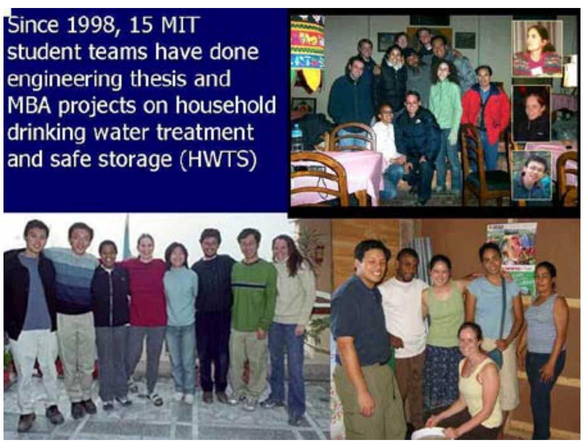


So it was at this International Women and Water Conference in Nepal in 1998 where three-quarters of the participants were from the water-poor world, were peasant women



from Nepal, representative of Nepali society because 90 percent of Nepal is a rural peasant population.

So this led me and my colleagues in Nepal and elsewhere to begin to address how we could supply safe drinking water to these women. It begins with this awareness of need. What is the need? The need is for children to be alive. We know these statistics.



So since 1998 my students -- 15 teams now so far -- have done engineering thesis work and also Sloane business students have joined our teams as well as others to address household drinking water treatment and safe storage.

I want to say that this is not a silver bullet, but it's one tool in a tool kit which includes hygiene, sanitation, and water availability. So there's a lot of interest in this right now, and I myself have devoted my attention to it for quite a while. But it's not the answer, it's one tool.

So we call this effort H2O1B -- Clean Water For a Billion People. As I say, MIT folks like numbers, so there's a good number to aim for. Our work is primarily field based engineering research. We've worked in Nepal and these other countries -- Dominican Republic, Haiti, Peru, Nicaragua, and just now Kenya this year. We've worked with NGOs, with municipal governments, with research labs, and with development organizations. We couldn't do this work without our partners in the countries we work with.

We've also produced a body of material which is available on our web site. I can give this to folks as I race through.

So what my talk is going to focus on is what are the existing household treatment technologies that are out there, and I should say that while say Brita systems, PuR systems, have been out in the first world for a while, I don't quite know how many decades perhaps, it's not that the idea of household treatment is new, but the idea of focusing on improving and innovating on household systems in order to provide safer water for the billion who lack access, the dollar a day people, the people at the bottom of the water food chain, the bottom of Tom's pyramid, the people who have the basic need. Those are the folks that we're focusing on. And systems specifically addressing their needs have not been a subject of research until the last decade at most.

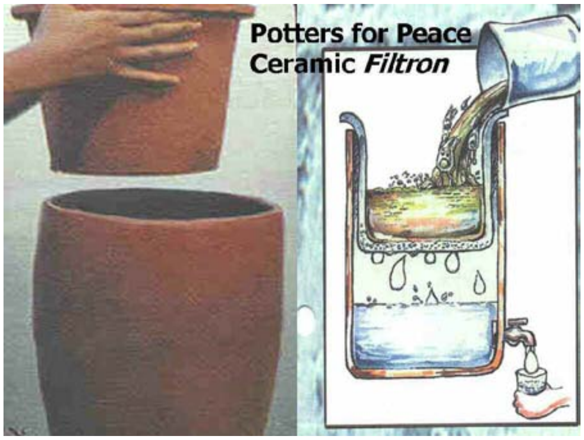
We have in the audience Erik Mintz and the folks from the Center for Disease Control Safe Water Program have been pioneers in that for about ten years. I'll be describing SODIS, the work for which began at Beirut University in Lebanon and moved then to the Swiss Technical Institute. That's probably also about a decade own. And my own work and work that's beginning to go on in other universities is no more than a decade old.

My students and I have looked at a wide range of what are the available technologies in the developing world to treat water to a safe level at the household. There are filtration systems using cloth, ceramic and sand; there are disinfection systems like the CDC's safe water system or the Swiss Technical Institute's SODIS system; coagulation, flocculation systems, Greg Allgood is here from Proctor & Gamble and they've been pioneers in the PuR product. He will probably talk about that tomorrow. As well as chemical removal systems for the big ones like arsenic, like fluoride, which are affecting millions around the world.

So a cloth filter is about as simple as you can get. It's a piece of cloth and you filter your water before you drink it.

Ceramic candle filters are available in the market places in countries like Brazil and in India. They're typically bought by the middle class. You see them in China as well. People typically boil and filter using these.

When my students began testing these from a number of countries we found they weren't working very well. They weren't removing microbially, micro-organisms. It goes without saying that the largest cause of waterborne illness in the developing world are microbially contaminated water supplies. I'm



assuming you know that, but our focus has mainly been on that. But the more recently has been on the chemical contaminants such as arsenic and newly on fluoride.

So these are some examples of what's in the marketplace in India and Nepal, but also in the first world, and we try to kind of marry the low cost and locally available kind of aspects of the technology from say India or Nepal with the quality control and the kind of certification and mass production sort of lessons that we can take from say a Dalton in the UK or a Swiss candle filter.

Here's another example of the Powders for Peace filter that's becoming widely available in Nicaragua and throughout Central America. It's also being scaled up in Cambodia and in Ghana.

The bio-sand filter is a slow sand filter, scaled to a household level so it's an intermittent household filter insofar as you can feed it water when you need, and it comes out the tap or the pipe.

The safe water system is the Centers for Disease Controls program of point of use treatment using a locally available chlorine product, safe water storage in an appropriately designed vessel, and education. So that's a package that they've been promoting since 1992, since the cholera epidemic in South America. And Erik I'm sure will talk more about the safe water system.

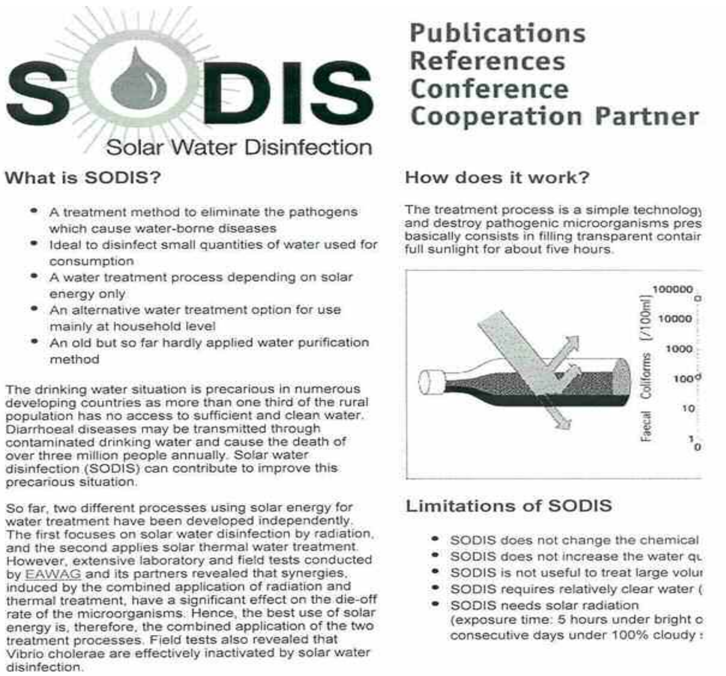
My teams have tested this approach, piloted this in households in several countries, in Nepal, Haiti and in Peru.

Safe storage is an important component of those three prongs of the safe water system approach, and that is important because if folks, women and children are collecting water from long distances there is a good possibility that the water will become contaminated even if the source is clean, even if it's a good groundwater supply, let's say, but they're carrying it for a kilometer back to their home. Are they putting it in an open bucket? Are they putting their hands in? Are children playing around that area? So having these

safe storage containers is a very very important part of safe household treatment.

This picture on the right is one that I took and it's very moving to me. This is a hospital in Yanze Province with a child, sick from waterborne disease, beside which is a safe storage vessel so that the oral rehydration therapy that this child is receiving, that she or he is receiving with safe water, water that has been treated with the locally produced chlorine product. It's branded as Water Guard. And it's in this safe container which has a narrow mouth, a spigot, and is using yet a locally available, locally made, so-called modified clay pot.

My students have been working with the CDC in Kenya to help improve the production of the modified clay pot.



SODIS
Solar Water Disinfection

Publications
References
Conference
Cooperation Partner

What is SODIS?

- A treatment method to eliminate the pathogens which cause water-borne diseases
- Ideal to disinfect small quantities of water used for consumption
- A water treatment process depending on solar energy only
- An alternative water treatment option for use mainly at household level
- An old but so far hardly applied water purification method

The drinking water situation is precarious in numerous developing countries as more than one third of the rural population has no access to sufficient and clean water. Diarrhoeal diseases may be transmitted through contaminated drinking water and cause the death of over three million people annually. Solar water disinfection (SODIS) can contribute to improve this precarious situation.

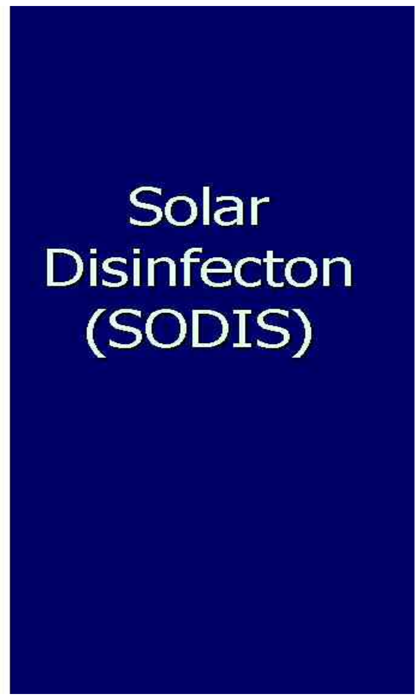
So far, two different processes using solar energy for water treatment have been developed independently. The first focuses on solar water disinfection by radiation, and the second applies solar thermal water treatment. However, extensive laboratory and field tests conducted by EAWAG and its partners revealed that synergies, induced by the combined application of radiation and thermal treatment, have a significant effect on the die-off rate of the microorganisms. Hence, the best use of solar energy is, therefore, the combined application of the two treatment processes. Field tests also revealed that Vibrio cholerae are effectively inactivated by solar water disinfection.

How does it work?

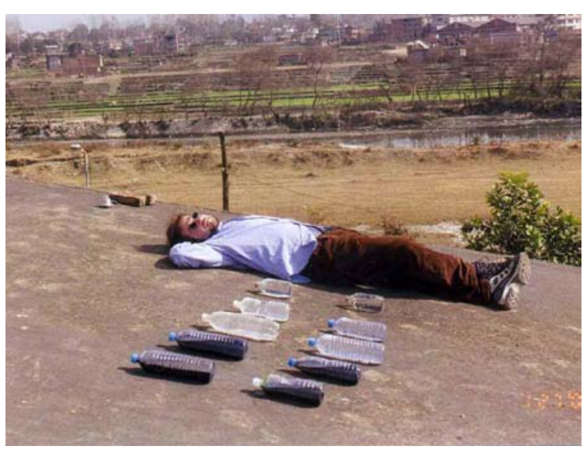
The treatment process is a simple technology and destroy pathogenic microorganisms pres basically consists in filling transparent contair full sunlight for about five hours.

Limitations of SODIS

- SODIS does not change the chemical
- SODIS does not increase the water qu
- SODIS is not useful to treat large volur
- SODIS requires relatively clear water (
- SODIS needs solar radiation (exposure time: 5 hours under bright c consecutive days under 100% cloudy s



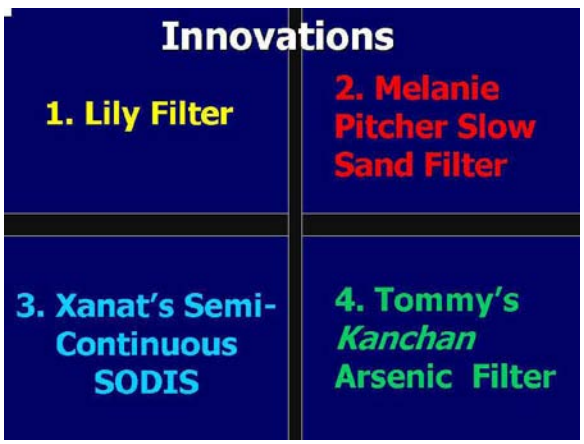
Then there's SODIS. Has everybody heard of SODIS? Solar disinfection in PET plastic bottles. So it you take your water bottle from your table here and take the label off, and if you have a contaminated, but not too contaminated supply. Not as bad as those yucky pictures of the surface waters that I was showing you, but water with a moderate to mild turbidity. If you take that water and put it in the sun for one to two days, depending on where you are in the world, depending on the latitude, depending on the cloud cover, that water will be disinfected by UV light in one to two days. So this is a marvelous, simple technology that's been well studied now, as I say, pioneered at American University in Beirut and for many years now at ETH in Switzerland as well studies that we and others have done at MIT. This is my student doing his studies of a SODIS process in January which is the coldest month, so the most challenging month in Nepal some years ago.



There are the existing, the coagulation disinfection products like PuR of Proctor & Gamble which Greg will talk of, and Water Guard which probably Erik will talk about.

There are also household drinking water treatment systems for the removal of chemical contaminants. For example, arsenic filters or deflouridation filters. I imagine that you, Yasmina, will talk about your deflouridation filter.

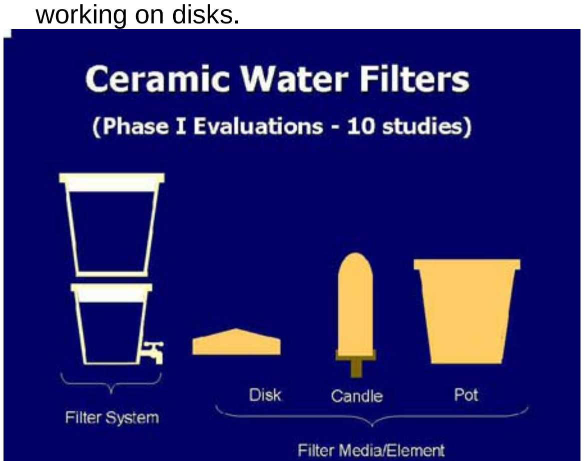
So now I want to talk about some innovations. In addition to my students studying existing systems that are out there in field sites to see how they work, and studying them not only for their technical performance, mind you, but studying them holistically, studying them in terms of how people are using them. The behavior use component. And studying how these fit within the economics of people who are earning a dollar a day.



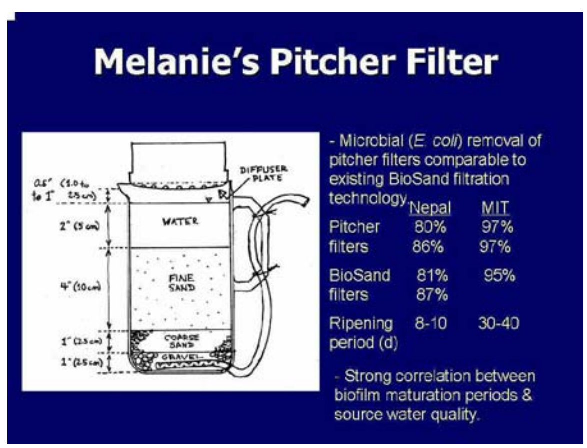
From that experience we are also beginning to innovate on these systems. So I'm going to tell you some stories about some of the innovations that have come out of our lab. For fun and for presentation purposes, we've tended to name these innovations after the student who was the kind of lead person on that team.

So the Lily filter, Melanie's pitcher filter, Shenat's semi-continuous SODIS, and Tommy's arsenic filter.

So the ceramic filter begins with an understanding of what kind of ceramic filters are out there. There are disks, there are candles, and there are pots. These are examples of all three types. And we've gotten excited about the idea of disk filters because we think that they can be mass produced very quickly and simply in many workshops around the world. So we've been working on disks.

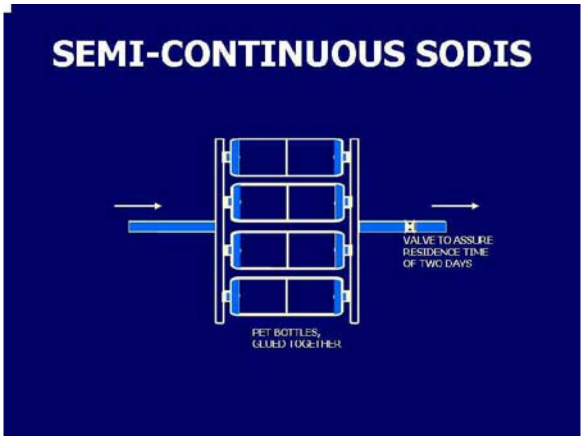


And we've done this project in collaboration with the mechanical engineering department, and Lily, the student there, came up with a prototype system for the disk filter which would have a removable cartridge in the middle. One of the problems with the candle filters which are the most widespread used filters, ceramic filters, are that you need to clean them regularly. That's true of all ceramic filters. But when you clean them, when the householder takes them apart, you have to unscrew a little wing nut and take it out and scrub it, it's very typical that the ceramic part falls apart from the plastic kind of holder. So we thought a disk would help to avoid that, but that a cartridge would enable you to kind of get at the filter for cleaning more readily. So that's the concept. We haven't won any prizes or moved that one forward yet in the last six months, but just one idea.



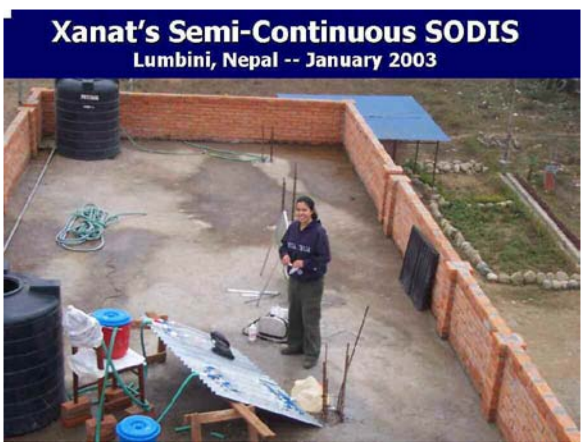
The next idea is Melanie's pitcher filter. It's the idea of the household slow sand filter technology but scaled down to pitcher size. Melanie, recognizing that the household slow sand filter when she did her studies a couple of years ago was costing about $25 to $30 in villages in Nepal found that most people couldn't afford that amount of money. So in the marketplace she could buy these pitchers for pennies and recreated her experiments at that scale, and did very meticulous and interesting work on the kind of household scale, the sort of full size slow sand filter with these

pitcher filters and found basically identical removal rates in the full scale versus the household tiny pitcher scale. This is Melanie at her site doing her testing.

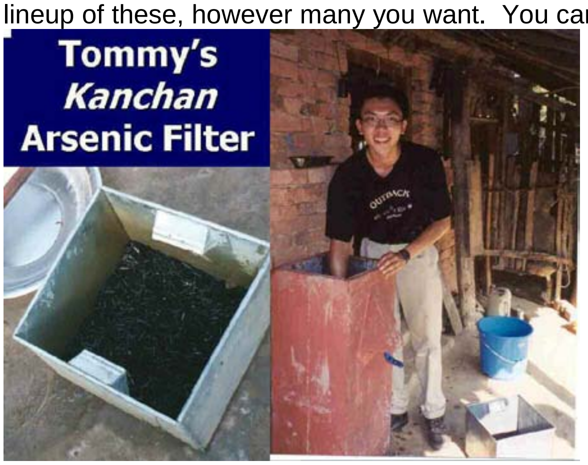


Then if we take the SODIS concept, one of the feedbacks that we got from villagers, and in fact Rochelle Rainey here in the audience is an expert on this whole subject because she did her PhD on social acceptability of the SODIS system. One of the feedbacks that we got early on was that it was a lot of work to put so many bottles out. If you had two days in Nepal in January that you needed to have these bottles in the sun, and you had a family of six, let's say. You'd need your day one bottles and you need say four liters per person per day. You'd need your day one bottles, your day two bottles, your in the house bottles, and guess what? It's the housewife who has to do all this bottle shifting, right? And at the same time it's these same housewives who are doing the heavy lifting in the agricultural work and who are also carrying the water long distances and caring for the kids.

So the feedback from the women was this is too much work. It's not that we don't want clean water, it's just that this is too much work. So it's the social side that was going to be the downfall of this.



With that in mind we got the idea of semi-continuous SODIS. And Chanat spent her year figuring out first how to cut the bottoms of these bottles off and what kind of glue you could safely and securely stick two bottles together. It's a little bit hard to see, but she's got two one-liter bottles stuck together and then she's got some connecting pipes so that you can do a whole lineup of these, however many you want. You can see it a little bit better there. But basically the idea of re-using these bottles in a sort of very simple household semi-continuous system.



The next and I think final innovation is Tommy's work with the Canshan arsenic filter. Canshan is the Nepali word for mountain spring water, and this was a team effort to figure out how to remove arsenic in Nepal and elsewhere from the groundwater supplies.

Our first effort in doing this arsenic testing and remediation was that an earlier student of mine, Jessie Herd, had brought from Pennsylvania, from a steel manufacturer in Pennsylvania, iron filings that we knew were effective at removing arsenic from water. We brought those to Nepal and we brought those to small town Nepal. We're talking ten hours from the capital in the middle of no where, a two street town and very high levels of arsenic in the groundwater there.

So we run the contaminated water through these iron filings and presto, the arsenic is removed. Then we think well what do we have locally that we can get that's kind of the equivalent of these Pennsylvania iron filings? And we walked, Jessie and I, the one market street, and what was in the marketplace that we could find that was close to iron filings? It was iron nails.

So you'll see in Tommy's invention, basically Tommy got the idea of combining the slow sand filter technology, which is a filter designed for microbially contaminated water with a kind of upper container into which we put first iron filings, but then iron nails.

And this is actually the result of many years of work and eight different technologies that we've tested, but this is the best so far for this setting. We've developed four different containment systems with the latest being the red bucket on the right. We've done, and this is early data, but we've done a pilot study that lasted for a years studying 16 filters in households. On the average, arsenic removal was 93 percent.

The flow rate is also very good with these systems. It's 14 liters per hour. You contrast that with the ceramic filter. You'll be doing good to get two liters per hour in a ceramic water filter.

Last year, December 2003, our team won a World Bank competition, were among the winners of a World Bank competition and that gave us $115,000 to implement this technology further in Nepal. So with partners,

Technical Performance – Phase II Testing

AKF 6-Month Filter Pilot Study (n= 16)

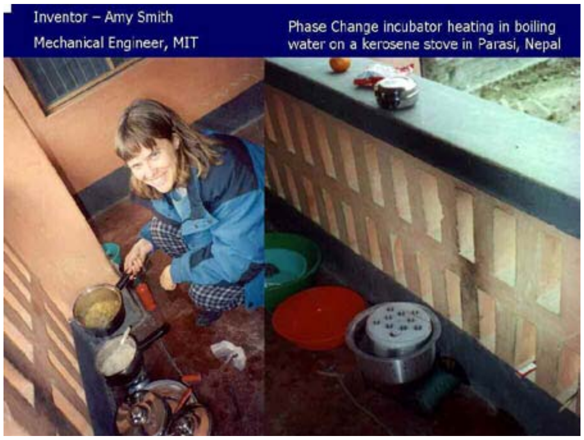
Technical Indicators	Average Results
Arsenic Removal	93 %
Total Coliform Removal	58 %
E. Coli Removal	64 %
Iron Removal	93 %
Flow Rate	14 L/hr

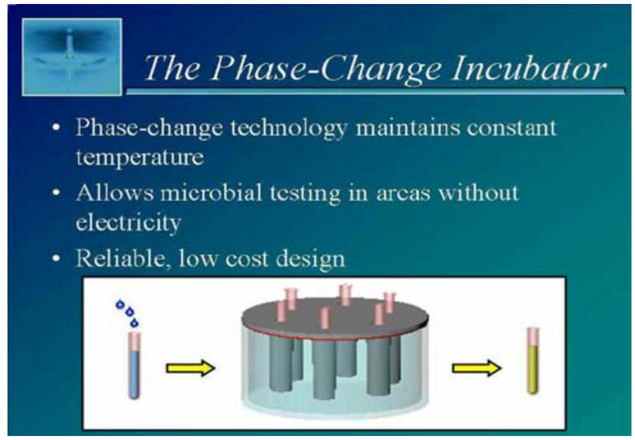
and our key partner is Rochanne Chestra on the right in the green jacket from, he's the Director of the Environment and Public Health Lab in Nepal, we've done seven activities, established an in-country Canshan Arsenic Filter Technology Center. We've trained and certified local entrepreneurs. We've run orientation workshops for government and for villagers. We've monitored 2,000 filters over the 2004 years and we're still seeing this 90-plus percent arsenic removal, monitored for these parameters, and we've continued R&D.

We sent a team of business students over in March of 2004 to help us with the marketing. Two of that team on the far right, working with Tommy, my engineering student, came up with this red bucket model that you saw before, and that's been able to allow us to lower the price from about $30 to about $15. It's still too pricey, but it's the best we can do so far. So we've done that with the Business School help.

This is the closing slide on the arsenic canshan filter. This is in a school in the arsenic-affected area.

So with the time I'll just tell you of one more innovation. I've just come last night from a McArthur Fellow celebration for MIT's three newly inducted McArthur Fellows and one among them is a woman named Amy Smith with whom I've worked for a number of years. She is an amazing inventor and human being. She and I have field tested her invention of the phase change incubator. She's done a lot of work





besides on the phase change incubator on technologies that would help us improve laboratory methods in field conditions in developing countries.

So her phase change incubator idea is to use a phase change chemical which she has selected because it specifically changes phase from solid to liquid at 37 degrees C which is typical incubation temperature. She puts this into a Tupperware container and then when you heat this up on a Bunsen burner or a stove, some kind of heating source where you can boil water, so you put this into a pot, boil it, melt it, and then it will, if you put it in an insulated container, it will maintain that 37 degree temperature for, it depends on the outside temperature, but about a day. That enables us to, as you can see here, do simple presence/absence tests, coliform testing for determining whether the water supplies are in fact contaminated. So that's another cool innovation.

Just to acknowledge my students and my department, our partners in Nepal and some of the foundations that have supported this work. That's it.

[Applause].

Erik Peterson: I'd now like to introduce our third panelist, Judith Barry, who is the Program Director for Municipal Programs from the Alliance to Save Energy organization.

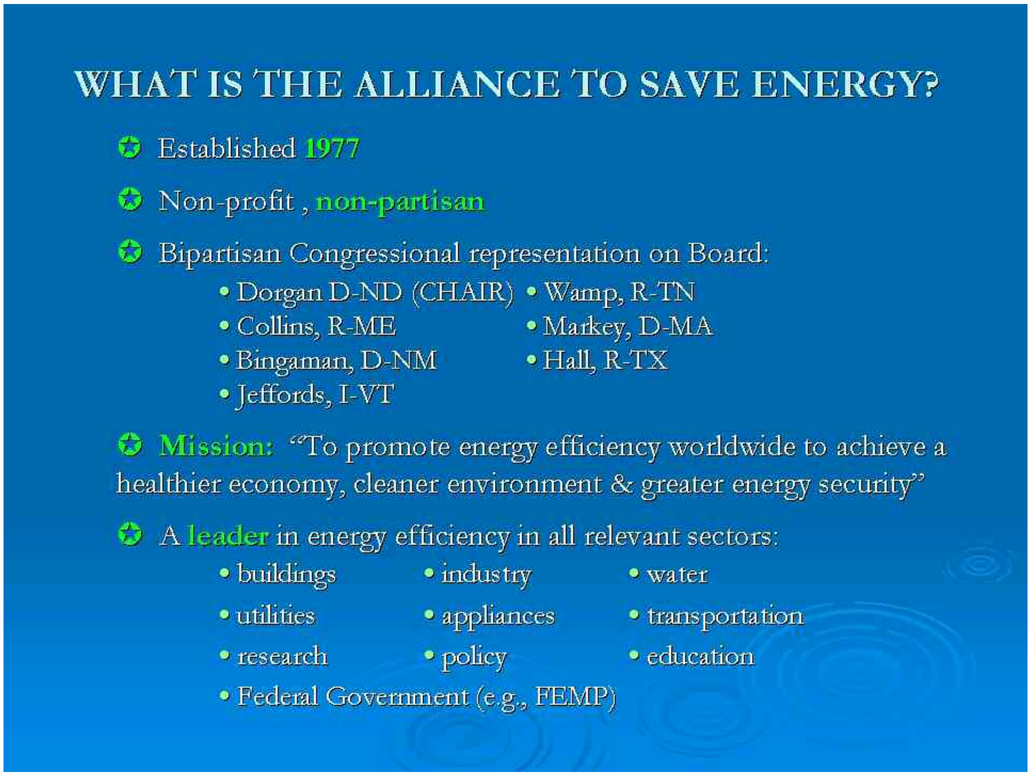
Alliance to Save Energy is a longstanding non-profit organization that promotes energy efficiency in the United States and abroad. The programs that Judith oversees works with municipalities to improve the efficiency of their operations, especially relative to water supply and heating systems.

Before coming to the alliance in 2004 Dr. Barry served for seven years at USAID as an environmental program manager and also as an AAAIS Diplomacy Fellow where she focused on energy efficiency and global climate change. Prior to her career in energy and international development, Dr. Barry spent nine years as a research biophysicist at the National Institutes of Health in the University of Arizona. Judith?

Judith Barry: Thank you for inviting me.

My talk is going to look at water from the perspective of energy, and I'll give you some examples of how closely related those are. First of all I'll give you an overview.

First I'll introduce the Alliance to Save Energy. It was established in the '70s by Republican and Democratic Senators Hubert Humphrey and Chuck Percy in response to the oil crisis, and an important feature about the Alliance, in addition to being non-profit is it's non-partisan and that helps us have a certain amount of influence, because people take us seriously. They don't associate us with one side of the aisle or the other.



You see that we have bipartisan congressional representation on the Board. They're quite involved.

Our mission, as you can see, it makes everybody happy. This mission statement is promote energy efficiency worldwide for a healthier economy, a cleaner environment, and greater energy security. Energy efficiency does do all of that.

As you can see by the bottom bullet we are a leader in all facets of the economy and of society that deal with energy -- buildings, utilities, appliances, transportation, all of it.

So "Watergy" is an important program in the Alliance. We coined the word because of the nexus between water and energy, they're so closely related. It's a program that, simply put, helps cities to distribute their water and treat wastewater efficiently which saves both money and water.

It's important, as you know, because of water scarcity which is important around the world, as someone mentioned South Asia, of course the Middle East and even here in the U.S. west of the Mississippi. Water utilities in the U.S., just for example, spend about $2.2 billion every year on electricity to move water around and to treat it. Four percent of all energy consumed in the U.S. is used to deliver water and treat wastewater which doesn't sound like that much except when you think about how much energy we use as a nation.

It's incredibly cost-effective. As they say, energy efficiency is one of our greatest sources of energy.

In developing countries in particular, you get very rapid payback periods. It's not uncommon in developing countries for cities to spend 50 to 60 percent or so of their budget on water supply. And even in the U.S. some cities, depending on the situation, can spent around 40 to 50 percent of their budgets on water supply and treatment. So it's a big issues and it's something that once people understand it they're very interested.

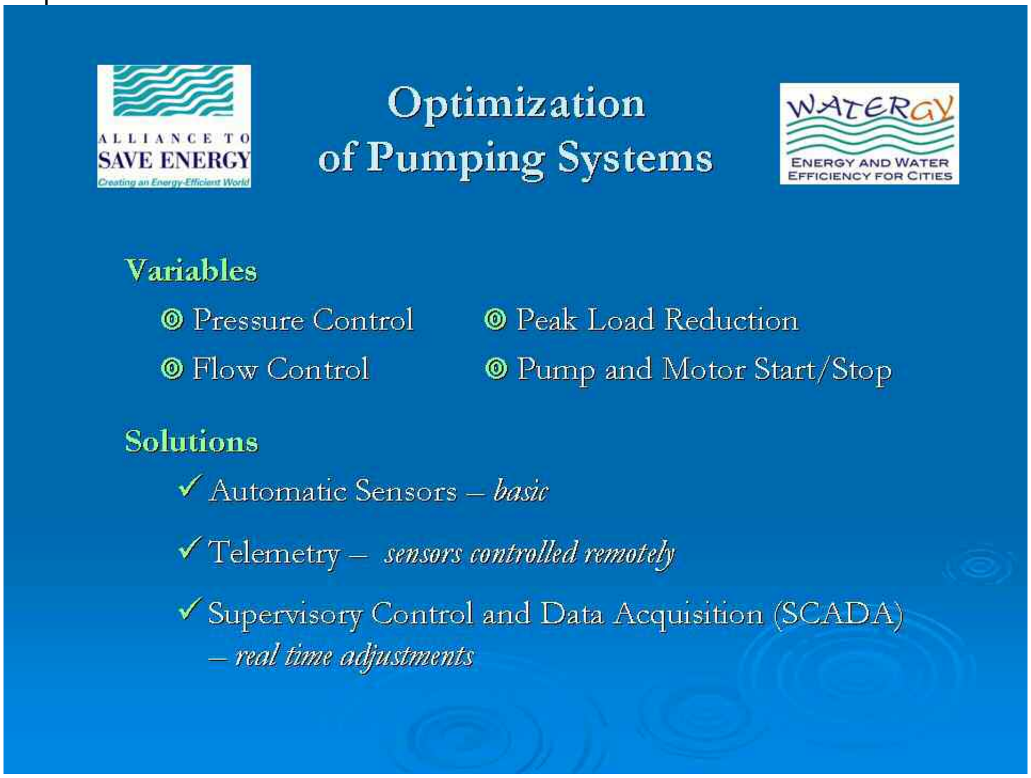
There are a lot of low and no-cost measures that can be done within a water system. We're talking about technology here today, but Watergy stresses a lot the low and no cost measures that can be taken, and we very much take a managerial approach. There are a lot of things that can be done on O&M improvements, for example, aside from replacing pumps and automating your system.

So it's common for the measures that we take in any given city to have payback periods ranging from right away to two years or so. And generally you can save about 20 percent of an energy budget by taking these Watergy measures.

And of course this also reduces the need for new infrastructure from new water sources.

This lists some of the stages in water supply and treatment. Each one of these takes energy, quite a bit of energy depending on your particular situation. If your water supply is well below you in terms of elevation or far away, or if it needs a lot of treatment to become potable and palatable. Some of these steps can be quite energy intensive.

Steps like automation can make it so that you can, for example, do the equivalent of peak saving so you can adjust your controls so that you're pumping water when the prices are lower, for example.



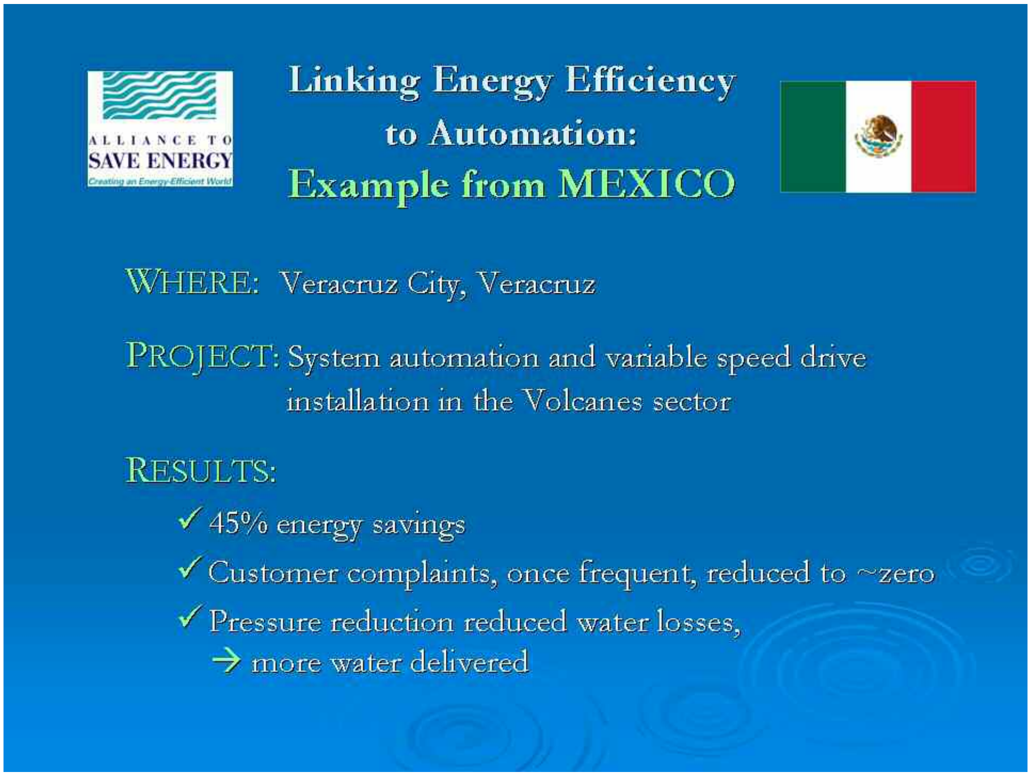
This shows some of the ways you can optimize your pumping systems. Water supply, most of the water is spent pumping. So the variables that you have to play with are pressure and flow control, peak load reductions where you can save a lot of money, and also pump and motor starting and stopping -- that is when you do it and how you do it. Again, you do it when the peak rates aren't at their highest, and how is, for example, variable speed drives.

So you have various solutions, technological solutions to this. The most basic ones are automatic sensors. There's also telemetry where you can have remote control over the system. Then beyond that, supervisory control and data acquisition -- SCADA -- where you combine the sensors and controls for real time adjustments to your systems.

I wanted to go through three examples that really illustrate how important Watergy, as we call it, this water-energy nexus, is for municipalities. I'll use two examples from the Alliance, the Watergy program, and then one from the U.S. that we actually weren't involved with.

This example from Brazil, we did this with the state water utility from the state of Ceara, this is Pajese, and it was in Brazil's arid northeast region where actually saving water is probably more important than saving energy, but you do both. And the technology used here was automated pressure controls, an energy management system, basically. Automated energy management system. The results really show how phenomenal this Watergy approach can be.

It saved 7,000 megawatts per year, and this was happening at the same time that they were able to save so much water from their pressure management system that they were able to provide access to 88,000 households that didn't have water before, didn't have piped water. And in the process this saved $58,000 in just two years and it had a payback of only seven months.

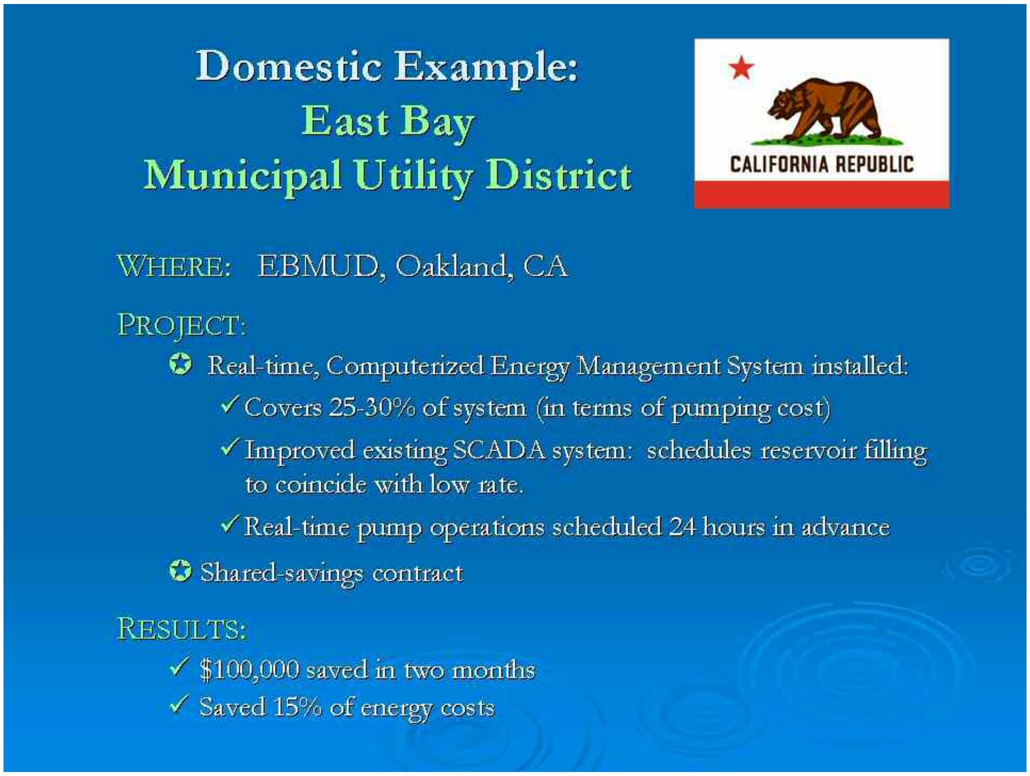


Another example is from Veracruz in Mexico, in the state of Veracruz. The technology here was again, system automation and installing variable speed drives in this one section of town called Vulcanes. This is an example where not only were there technological improvements but managerial ones. In this case there was a situation where you had two wells that were basically competing against one another, working against one another in pumping water. So part of the solution here was just to rearrange the system so you only had the one well being accessed.

In this case, again, very impressive energy savings, 45 percent. The reduced pressure from the pressure management approach that was taken, reduced water losses because like many developing countries these water supply systems are very leaky. So you reduce the pressure, reduce the leakage. You mainly do that at night. Then you can deliver more water. So it's not only a matter of saving money, saving energy, saving water, but you also because of all of that, you can deliver more water to poor households that don't already have it.

In this particular case there were constant complaints from consumers because of the poor pressure and just the spotty provision of the water, and those have all but gone away.

So in developing countries in particular the Watergy technique, the Watergy approach is very beneficial because when you've got half or more of the municipal budget taken up by moving water around all the efficiencies you can get there save you energy which is often in short supply in developing countries; saves water, which is often a problem; and then the money saved also allows these municipalities which are usually very cash-strapped to provide better and more services to their citizens.



Here's an example from the U.S.. It wasn't one that we're involved with, but just to show you that in the U.S. as well there are a lot of opportunities. Even though we're not the low-hanging fruit that these developing countries are and our systems aren't as leaky but there are still a lot of potential for Watergy approaches.

In this case, this was in Oakland and the project was to have a real-time energy management system that was computerized. It covered about a quarter of the system in terms of the pumping cost. And the main technological improvement was to improve their existing SCADA system so that now it schedules the filling of the reservoir to coincide with when the electricity rates are lower and when the demand is lower. Before it just, when it sensed that the level was dropping the pumps kicked in and it didn't do it according to demand or electricity rates. This was done by a shared savings risk/reward contract, like an Esco type contract. It saved $100,000 in just two months, and it saved 15 percent of energy costs.

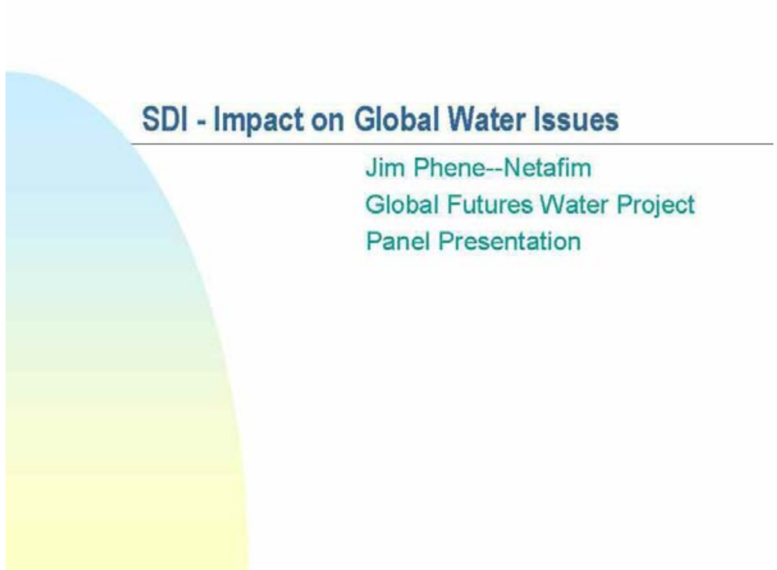
That's it.

[Applause].

Erik Peterson: Thank you.

I'd now like to introduce the fourth and final panelist in this first panel of the afternoon. Jim Phene works with Netafim is a country that was established in 1965 and was a pioneer in the important technology of drip irrigation. So far we haven't talked a whole lot about the agricultural sector. Clearly agriculture is an enormously important water use sector. Jim has been five years with Netafim. He has been involved in work on irrigation-related issues since 1982 and has worked with a wide variety of irrigation systems from mechanized irrigation, drip irrigation, water delivery control gates, and he has worked in both the western United States and Australia.

Jim?



Jim Phene: Thank you. It's a pleasure to be here, and as I look around the room I think one of the things that comes to mind immediately when I address this group, I have to applaud your public spirit in terms of coming up with a water policy that will not only affect the United States but maybe for the betterment of the entire world.

One of the things that also comes to mind when I sit up here and was listening to the presentations, the majority of what I've read and seen surrounding this specifically deals with symptoms that probably accrue from the 90-some-odd percent plus of irrigative practices throughout the world which is flood, furrow -- technologies that are thousands of years old, we don't even know how old they are.

A lot of the water quality issues that we're dealing with a lot of the water availability issues all accrue from, and I'm going to use a term, the mismanagement of water resources by the agriculture sector. I don't say it's mismanagement on purpose, because they try to do a good job. But they're dealing with infrastructures in some cases that are hundreds of years old if not older. So let me begin and we'll go from there. I'll show you how I think some improvements in irrigated agriculture could have a significant impact on the rest of your efforts.

I didn't know how long I was going to have to speak. I really had a hard time preparing for this presentation. I normally can speak anywhere from 45 minutes to eight hours, it just depends on what you want to know. [Laughter]. That's without jokes.

So I'm going to give you the answers right now so that if you want to go to sleep you won't miss the punch line. [Laughter].

Drip irrigation, particularly subsurface drip irrigation which represents a very small portion of irrigated agriculture, can save anywhere from 30 to 60 percent of the water that's currently used for irrigated agriculture. That is if that is your approach.

On the other side we can use the same amount of water and increase

production anywhere from 30 to several hundred percent, and I'll show you a few examples of that.

If we're looking at the population growth that I've read in some of the FAO documents, thank God I'm a speed reader because I never studied in college. I just crammed the night before. But I've probably read 700 or 800 pages of materials from FAO and ICID and when I was at the Academy, the American University, and I just thought about it when I drove in because their radio station was on. They used to run symposiums every year. They would bring in industry and governmental and people like yourselves and they would debate topics. Well, 25 years ago the topics that were hot were energy and corporate ethics. Funny how that sort of comes back to haunt us.

But when we talked about energy specifically, it was a sort of a doom and gloom thing, we were looking at Malthusian issues and they basically said we were going to run out of energy. I'm sorry, but humankind is pretty resourceful. We haven't run out of energy and now we're looking at new sources of energy.

So I think in this water situation if you read a lot of this stuff it's really doom and gloom, but the technology exists, as one of our panel members said before. It's here, it just needs to be presented in a way that we can expand it beyond the United States.

Then I guess the bottom line is in looking at the capacity and the value of water, we need to decide either in the United States or globally, what's the best way to distribute the water? In other words, what gives you the highest economic return?

So as a background we're going to talk a little bit about my experience, some observations, SDI, which is Subsurface Drip Irrigation. I'm going to leave out the economic viability at this point because of time but you can ask me about it later. Some new advances, then we'll leave it open for questions.

As I said, I got in the Air Force because it was right near the end of the Vietnam War and they asked me why am I going? I said well somebody has to do it. When I got out, they said why are you getting out? We'll give you SR-71s anything you want to fly, and I said no, like an idiot, and said I'm going to get out and change the face of irrigated agriculture.

Well here we are 18 years later and I get my first opportunity to actually make a larger impact. I've been working on the high plains of the United States and we've made some pretty dramatic improvements there, but it's just in its infancy.

A lot of experience with on farm automation, also I've participated in state level organizations that were interested in educating

people on water like the California Irrigation Institute, and currently I'm Vice President of the Central Plains Irrigation Association which deals with states in America that have water availability issues right now, like Kansas and Colorado and Nebraska, and I'll touch on that a little bit. Everything that's happening here in the U.S. is analogous to things happening elsewhere in the world. We just have the advantage of maybe more potential to invest here at home.

I've worked on water delivery gates, both in Brawley, California for the Imperial Irrigation District which is probably one of the most automated and advanced irrigation districts in the world; worked all over in Australia, particularly along the Murray River, so I'm familiar with the issues they had there; worked in the mechanized irrigation field; and most of my experience and everything I've done has always been in the pioneering or the building of markets. So this is a similar type of effort. Then I've worked in the drip irrigation market building a consensus that drip has the answers for some of the water issues plaguing the United States.

Some observations in case I get cut short, you never know. I try to get my message in up front, and then I run out of time. Education. It was in the keynote speech. Most of the major universities now if they had an irrigation program it's no longer available. We are not training irrigation engineers on a wholesale basis like we used to in the '50s, '60s and '70s so we do not have an education infrastructure at this point to train the new and upcoming people that are going to handle this problem for the next 50 years. So it's very important in anything that we do for legislation or for developing solutions that we address the supply of those educators.

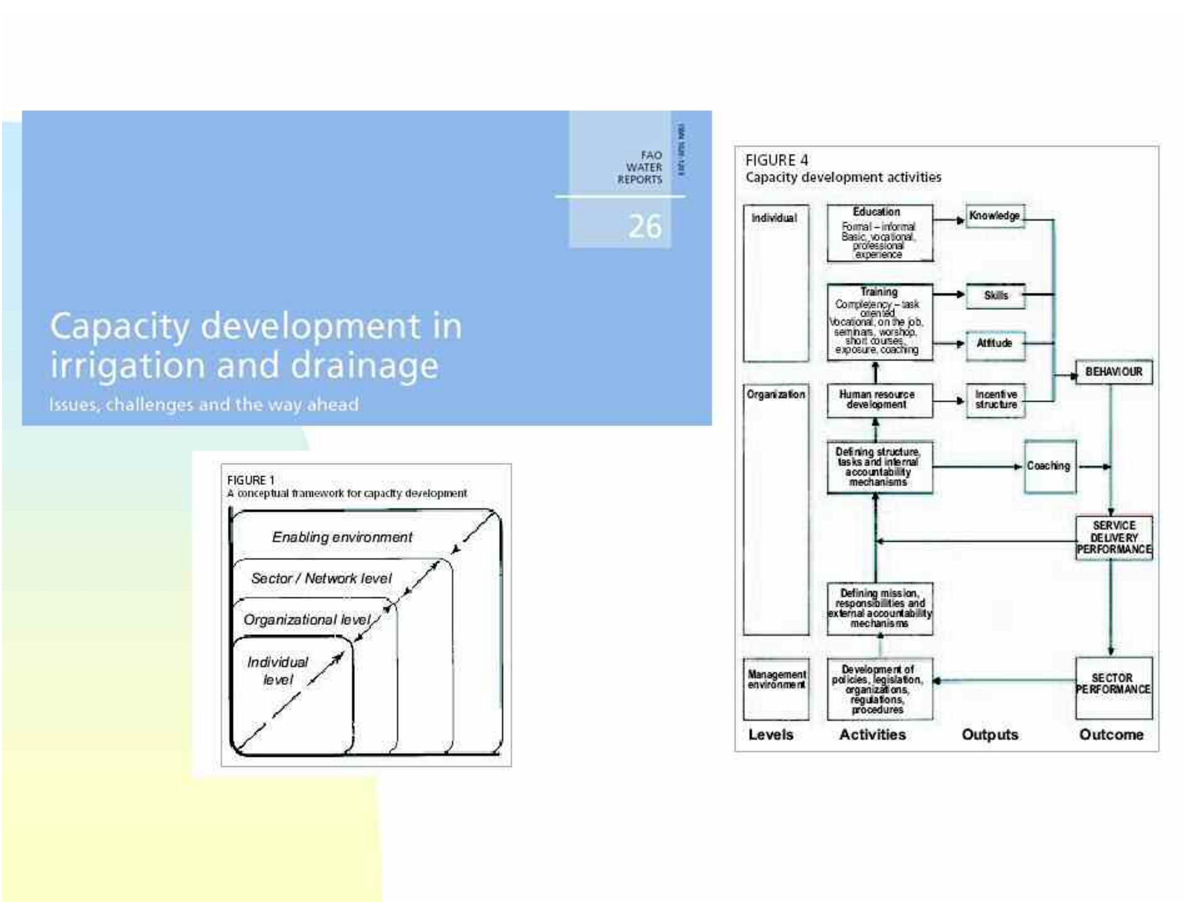
The next thing that I've seen, and I saw it particularly in my CII experience. California is a very water-intensive state. A lot of times we would run concurrent sessions. The policymakers would be in one room, the regulators would be in one room, the researchers and the growers would be in another room. Policymakers would make policy that really didn't connect with what the real world experiences of the growers and the researchers were pointing out. It's very difficult because it's a complex subject.

As I was reading through some of those papers -- I'm a psychologist, okay? I'm an irrigation -- Don't ask me how I got here. It must have been problem mentally. But the bottom line is, if you're going to make people accept new technologies the question that one of the guys in the audience asked earlier about the social science, it's very important, very important. Because if you're going to ask them to change their way of life, you're asking them to change a very basic inner feeling that's tough to overcome. We overeat, it's tough to change our ways, if we smoke, we drink, those things are tough. If you live a certain way you get used to it and change is very difficult. As I used to tell my ex-wife, the male mentality is if it's not broke, don't fix it. Okay?

The other thing that was mentioned this morning in the keynote speech is the dearth of research. One-tenth of what we previously spent on irrigation research and research on energy and those kinds of things is what we're spending now compared to the '50s. I can tell you my father did over 350 papers where he was the principal researcher, probably one of the foremost researchers on SDI in the world, and when he left and retired 12, 13 years ago there's been virtually no original research done since. It's a crying shame. We're working on getting the

universities in my territory, I've got seven or eight projects going with some very very good researchers, but we need to have that nationwide and we need to be the leaders in this area.

I guess the bottom line is, and I've found it true in everything that I've always done in any state, any local area, any region, any country, it's always the innovators that pick up these new ideas, these new technologies, that look outside the box and say look, I'm tired of the status quo, I want to change, I either want to make more money or I want to make my life better for those around me. So it's very important that whatever we do we start at the bottom so that we meet at the beginning.



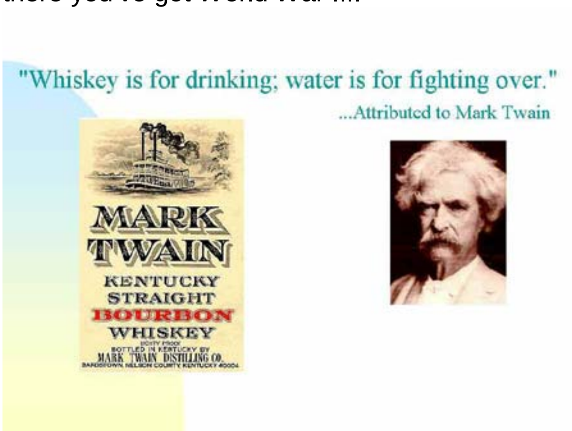
One of the things that I looked at in FAO-26 was they looked at capacity development and irrigation and drainage. That was one of the things we were supposed to address in our presentation. If you look at the individual level, they see that as the first step and I see that as exactly the case -- through education, through demonstration projects like some of the panel members have done here. That's the things that need to happen.

We won't go through this slide. We don't have enough time. It would take a week.

Maslow, pretty popular guy. I'm a psychologist. I've got to talk about him today a little bit. I'm going to talk about him more in terms of political unrest.

I think one of the things that we have to look at and one of the things that caught my attention was the potential here for us to not have to spend money on the military, and you're talking about an ex-military guy, but spend it on making people's lives better so that we don't have to use force. A very important fact.

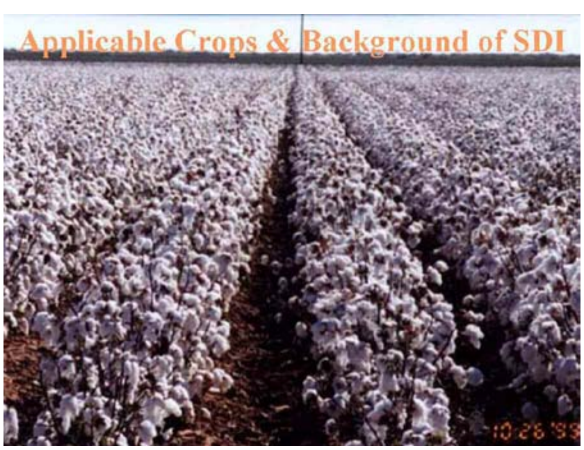
If we can fulfill their basic needs they're going to have a lot lower level of anxiety. Anxiety also feeds their frustration. If they're frustrated, then their self esteem starts to take a hit. We never do get to the top. That becomes an endless cycle of the have's and the have not's. If we can meet the basic needs then people can look at other things to deal with. It's like the chronic complaint of your child when they're hungry. I'm hungry, I'm hungry, I'm hungry to the point where they get so cranky that you can't stand being around them. If there's a brother and a sister there you've got World War III.



I've seen this many places. I didn't know a lot of people were Mark Twain fans, but whiskey's for drinking and water's for fighting. If we look at the western United States there was a lot of battles fought over water. There's still battles going on over water. If you look at Colorado, it's a continuous battle between the municipalities, between industry and agriculture for who's going to get the water. And we can talk about some of those things that we've done there to make some improvements.

When I worked for one of the gate manufacturers I got a lot of experience down in Brawley, California, and Los Angeles is one of the biggest metropolitan areas in the United States. They have an entity called the Metropolitan Water District. They were paying money to the Imperial Irrigation District for water. If the Imperial Irrigation District could control or eliminate some shrinkage then they could sell that water to MWD. Well, when I was doing my merchandised irrigation stint, that happened to be part of my territory and we crafted a deal where MWD came in, subsidized the investment for the growers to put in more efficient irritation, we reduced their water use from six acre feet to three acre feet, and by the way, three acre feet is enough for 15 people a year, so that those growers could benefit both from the water sale and the agricultural output. The district got $75 for MNO and the grower got $125 for every water foot they saved. We were saving three acre feet a year. That's a pretty good income for that grower.

I used that same story in Colorado with the city of Aurora and we were just in the New York Times recently, I planted that seed five years ago. They came back in on land that they had already purchased and I would assume that the future deals will be crafted a little bit different, but they came back and they told those growers, look, we don't want your town to dry up so we're going to pay you $1400 an acre to put in the best drip system you can, you can farm it for ten years, and what they're going to find, I can tell you this, is those guys will continue to farm that and they'll still have enough water left over to be able to fuel their growth.



So what kind of crops is this applicable on? I tried to call and get some numbers, but I can tell you it works on everything including rice. We're probably talking about 1/8th to 1/10th the water to grow rice, which is a huge major water user.

On cotton, this is a picture in Texas. That's five bale cotton, somewhere between four and five bale cotton. The irrigated average of cotton in Texas, west Texas specifically, is about a bale and a quarter to a bale and a half per acre. These guys are doing this with three gallons per minute per acre which is less than 2/10th of an acre inch a day. The equivalent of 2/10ths of water covering an entire acre and they're getting these kind of yields. It's huge.

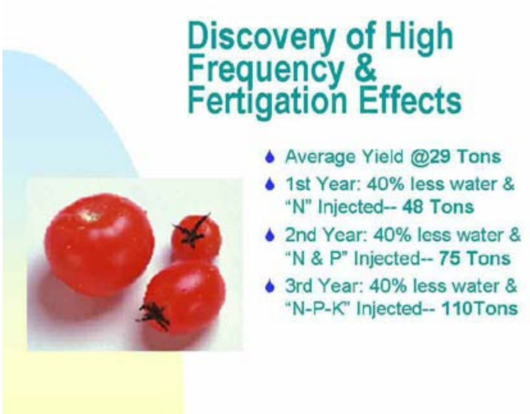
But it's also a foreshadow of what the rest of the United States is faced with where they're mining water or where water is in deep competition. These guys are having to move to other irrigation methods to continue farming.

In the high plains of Colorado, their mechanized irrigation has experienced a huge growth from the '70s into the '90s. Now there's not enough water to run a pivot. So we're seeing some significant changes.

I brought this picture specifically for the Senator. This is New Mexico. This is wheat. This is 5.5 ton wheat. This is in rotation with onions. A lot of our early drip stuff was done on onions and chiles in New Mexico 10-15 years ago. They're a leader in that particular area. But 5.5 ton wheat is huge. Normally if a guy gets two ton on irrigated wheat he's very happy.

Potatoes, 200 to 300 extra bags. Again, a staple in a lot of parts of the world. Vegetables, corn. If I can make an economic case for subsurface drip on irrigated field corn it can work for almost any crop in the world.

This is a little bit of the work that my father did, and I use this to sort of give you some idea of what kind of productivity accrues from using subsurface drip. He pretty much discovered, he coined the name SDI, but he discovered high frequency and fertigation effects back in the late '70s, early '80s, so we're talking a long time ago. This technology's been around.



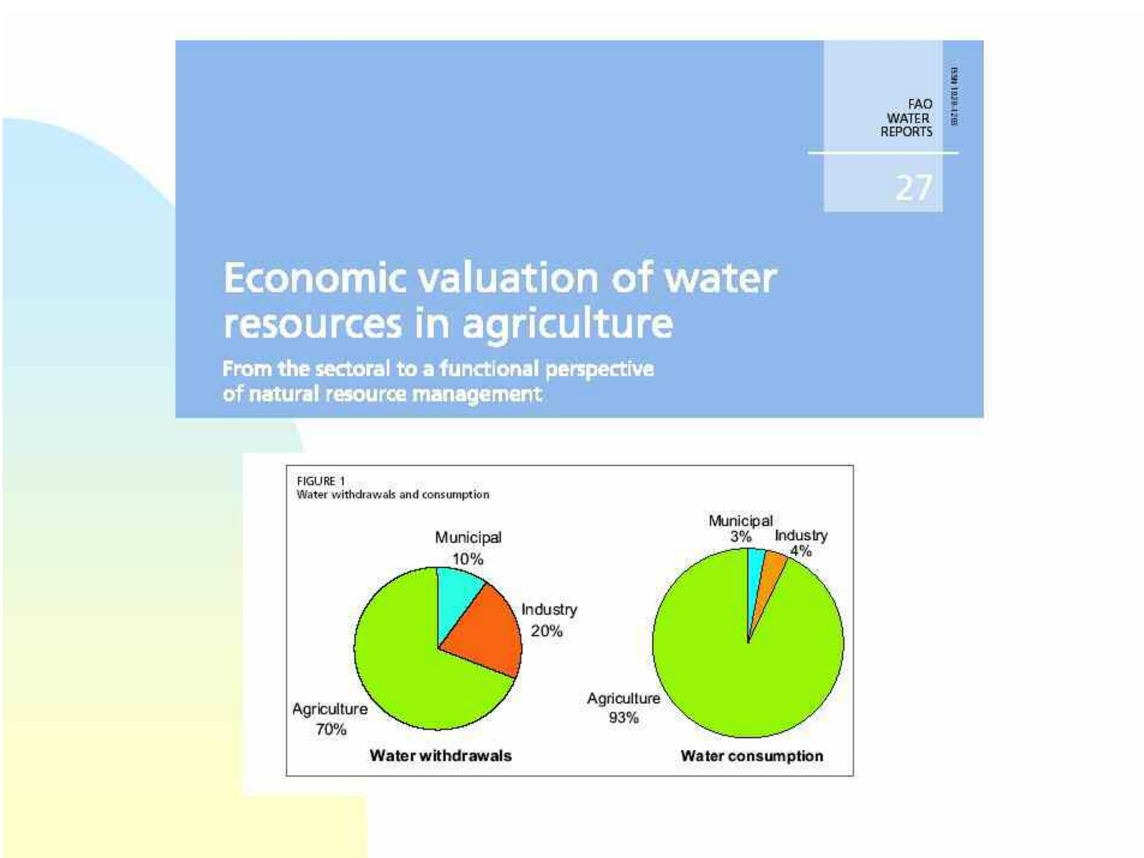
In California the average yield on processing tomatoes was about 29 tons. The first year they used subsurface drip, and there were some water issues -- sealing and runoff and those kind of issues so they tried this new drip stuff. They used 40 percent less water they injected in, and they got 48 tons of tomatoes to the acre. That's a pretty huge productivity jump. The next time they ran the project they still used a lot less water than the furrow, but the put in phosphorous as well, and they put it in the root zone. Phosphorous and potassium very well in the root zone. If you put them anywhere else they're not

usually available to the plant. Seventy-five tons. At that point NOVA got interested and came out and did a 20 minute subject on the work that they were doing out at the Fresno lab with the ARS.

The last year that they ran the project they got 110 tons of processing tomatoes, just by adding potassium to the mix. That's a huge jump in productivity, all with a significantly lower amount of irrigation water compared to normal agriculture.

Down at CSU, this was one of those serendipity things we talked about as far as research goes, accidental, but they basically got 1500 bags of onions on furrow and drip. The difference was almost six acre feet. A very significant amount of water. I don't know how many of you guys had those great strawberries out there that were covered with chocolate. Those are Driscolls. They're grown in the central coast of California. They use six acre feet of water to grow those. It only takes two, but they want to make sure they're good so they use that extra four feet of water.

This probably is going to catch most of your attention because this is the impact of SDI on water availability and quality issues, and I think that's one of the major issues that we're faced with as we look globally.



I looked in FAO-27, 70 percent of the water that's withdrawn from all sources is from agriculture, but 93 percent of all the water that's withdrawn or actually 93 percent of the water that's actually consumed, comes from agriculture or is caused by agriculture.

- In 1997, there were about 268 million hectares (2.68 million km2) of irrigated area in the world.
- Asia contains about 70% of the world's irrigated area.
- The area of irrigated land nearly doubled in the last four decades of the 20th century, mostly in Asia and the United States.
- In 1998, 18% of all cropland was irrigated; these lands produced 40% of all food grown.
- Ten percent of the world's agricultural food production depends on using mined groundwater.
- World irrigated agriculture accounts for 85% of all fresh water consumed. Without this irrigation water, the food produced by natural precipitation would be insufficient to feed the world's current population.
- Agriculture consumes much of what it uses, returning less than 30% to sources such as rivers and lakes from which it can be withdrawn by others.

This is too busy to read, but basically one of these things that caught my attention, actually two, was the irrigated area of land nearly doubled in the last four decades in Asia and the United States. Seventy percent of the irrigated land in the world is in Asia. And 18 percent of all crop land was irrigated and produced 40 percent of the world's food. That means less than 20 percent produced 40 percent. And I'm telling you, we're not even close to what we could do in that scenario.

I want to show you how much potential, and I know this may be hard to read but I'll just pretend you're blind and I'll tell you what it says. This is a sheet that I got from the International Committee on Irrigation and Drainage. There is not really good statistics on irrigation water in the world. I can tell you that right now. The United States is not very good either.

SPRINKLER AND MICROIRRIGATED AREAS IN SOME PARTICIPATING MEMBERS OF ICID*

(In order of decreasing percentage)

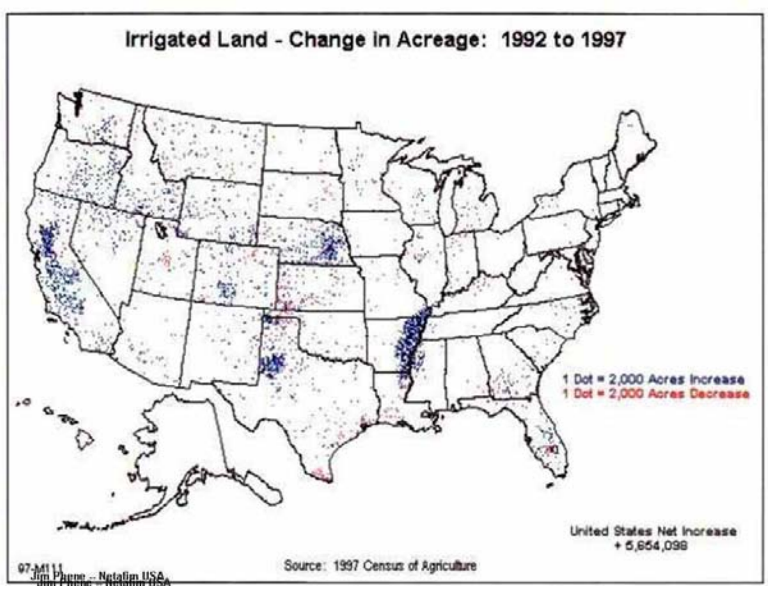
Country	Total irrigated area (Mha)	Sprinkler ha	Microirrigation ha	Total sprinkler & microirrigation, ha	% of total irrigated area
Austria	0.0800	760,000	3,000	763,000	100.0
Germany	0.5320	530,000	2,000	532,000	100.0
Israel	0.2310	70,000	161,000	231,000	100.0
Lithuania	0.0081	8,122	–	8,122	100.0
Czech Republic	0.1530	151,011	1,224	152,235	99.5
Great Britain	0.1600	156,000	2,000	158,000	99.0
Slovak Republic	0.3100	310,000	2,650	312,650	99.0
France	1.6100	–	–	1,450,000	90.0
Malawi	0.0550	43,193	5,450	48,643	87.0
Hungary	0.1300	85,000	4,200	89,200	68.6
Zimbabwe	0.1500	87,000	8,000	95,000	63.0
Jordan	0.0700	5,300	38,300	43,600	62.0
Macedonia	0.1730	100,000	500	100,500	58.0
Cyprus	0.0550	2,000	25,000	27,000	49.0
Spain	3.3400	800,945	562,854	1,363,799	40.8
South Africa	1.3000	255,000	220,000	475,000	36.5
USA	21.4000	3,380,000	1,050,000	4,430,000	21.0
Egypt	3.3000	450,000	104,000	554,000	17.0
Italy	2.7000	345,000	80,000	425,000	16.0
Syria	1.2800	93,000	62,000	155,000	12.0
Mexico	6.2000	–	–	600,000	10.0
Portugal	0.6300	40,000	25,000	65,000	10.0
Taiwan (Rep. of China)	0.4560	8,500	18,100	26,600	5.8
Australia	2.0000	–	–	100,000	5.0
Iran	8.0500	199,075	53,717	252,792	3.1
China	53.3000	1,200,000	267,000	1,467,000	2.8
India	57.0000	658,500	260,000	918,500	1.6
Total for these countries	164.6731	9,737,646	2,955,995	14,843,641	
		5.91%	1.80%		

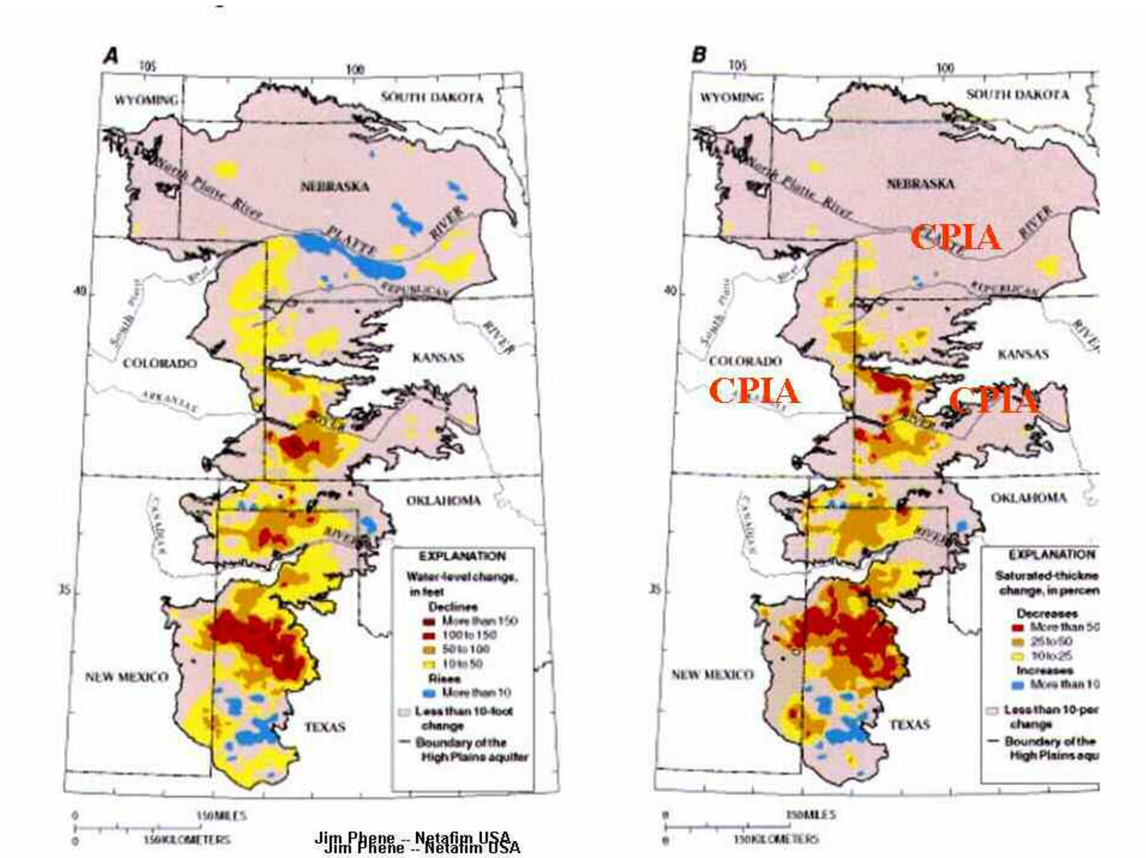
*Latest data as supplied by the respective National Committees/Committee

In California they don't have a clue how much water they use for irrigation. But you're looking at countries that would report, about 165 million hectares. I think there's 260, so about one-third of the countries don't report what they do. Out of that, less than six percent of those that reported use sprinklers, and less than two percent use micro-irrigation. So we could probably cut those numbers down again by another 30 percent or more. What we're looking at is highly efficient irrigation systems represent probably six or seven percent of the total irrigation systems in the world.

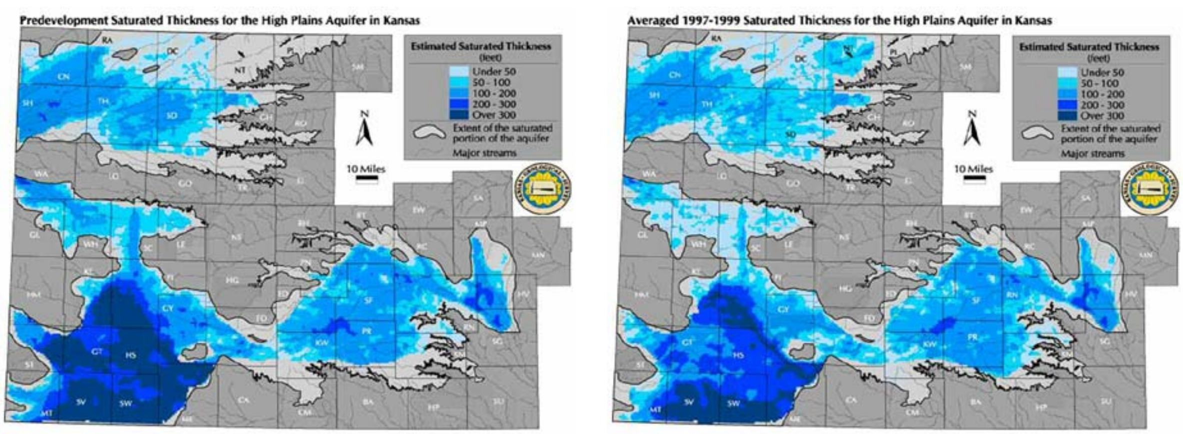
Well if I was running a manufacturing plant or any other kind of facility and I knew that 93 percent or 94 percent or 92 percent of my production capacity had a lot of room for improvement, I think that would be where I'd start looking first, because capacity and availability of water is going to be very important. We're going to need storage, we're going to need infrastructure for delivery, but the place to start is on the farm. It has to be a linked process. It may take 15 years to get a new dam in or to get a pipeline in to bring water from a dam, which by the way you could also use to generate electricity all the way along, but the guys on the farm can start right away.

Here's the irrigated land change in the United States from '92 to '97. I'm sorry I don't have the new chart yet, it just came out. But you can see there's the Ogallala Aquifer, there's a lot of red dots in there. Look at this change on the Mississippi. Remember that when I show you some slides down the road.





Here's the Ogallala Aquifer, a significant portion of our irrigated crops in the United States come from this basin. In fact if you really looked at all the acres that are here there's several times the amount of acres that are in the state of California which we all look at as a huge agricultural producer which produces 70 percent of our fresh fruit and vegetables for the United States.

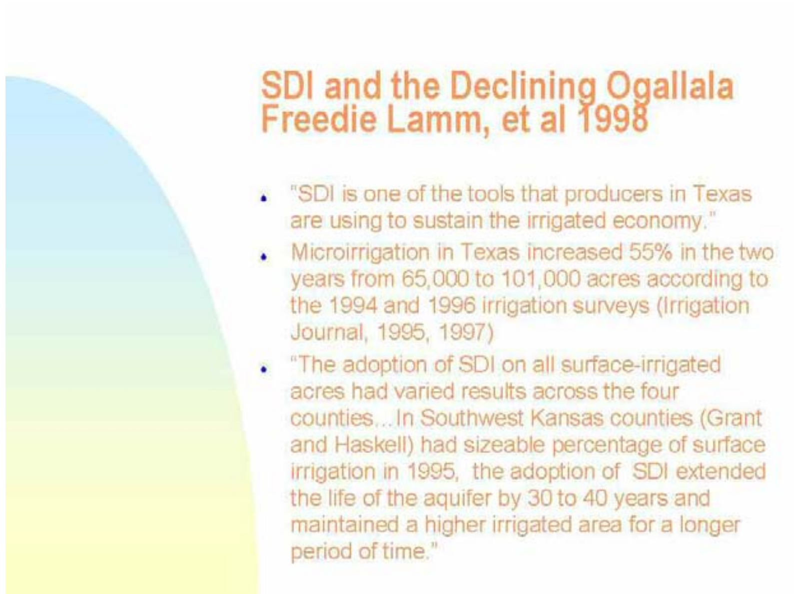


This is a redevelopment saturated thickness for the high plains in Kansas. The dark blue means it's over 300 feet thick. The light blue means it's under 50. Watch what happens here. This is as of '98. You can see that that area went significantly lower. If we go back to the previous chart you can see these dark brown areas represent a water change level of more than 150 feet, which is huge. It costs you a lot of energy to pump that extra 150 feet. And the change in saturated thickness, dark brown here, was more than 50 percent.

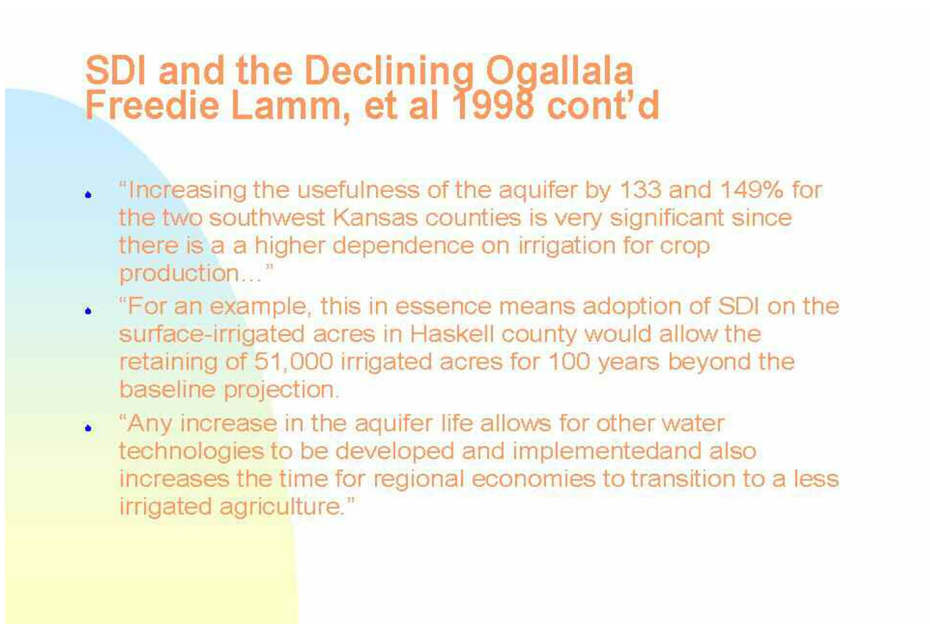
So that means in these dark brown areas we've already depleted more than 50 percent of the water.

There's a Dr. Lamm at K State. He did a really neat interesting thought process, and I presented this to you because I wanted you to think about it in terms of the rest of the world.

He looked at SDI. In Texas it's the only thing that's keeping their ag growing. The acreage there is probably over 150,000 acres. But he looked at what if I took all the surface irrigated acres in Kansas and I changed them over -- western Kansas, to be exact, and changed them over to SDI? He assumed that there was about a 65 percent irrigation efficiency associated with furrow, which is being very nice; but what he looked at was the adoption of SDI across that entire acreage would extend the life of the aquifer 30 or 40 years. That's a huge amount of money because every acre foot that is generated in Kansas as of 1999 was worth $805 in revenues to that state. It costs about $800 to put a drip system in. I'd say the payback is less than one year in terms of how the state looks at it.



In some cases those aquifers increased by 133 to 149 percent, so we're talking huge numbers. This is a place where we're looking at a significant amount of the acreage is covered by pivots. So we're just going in and fixing the furrow.



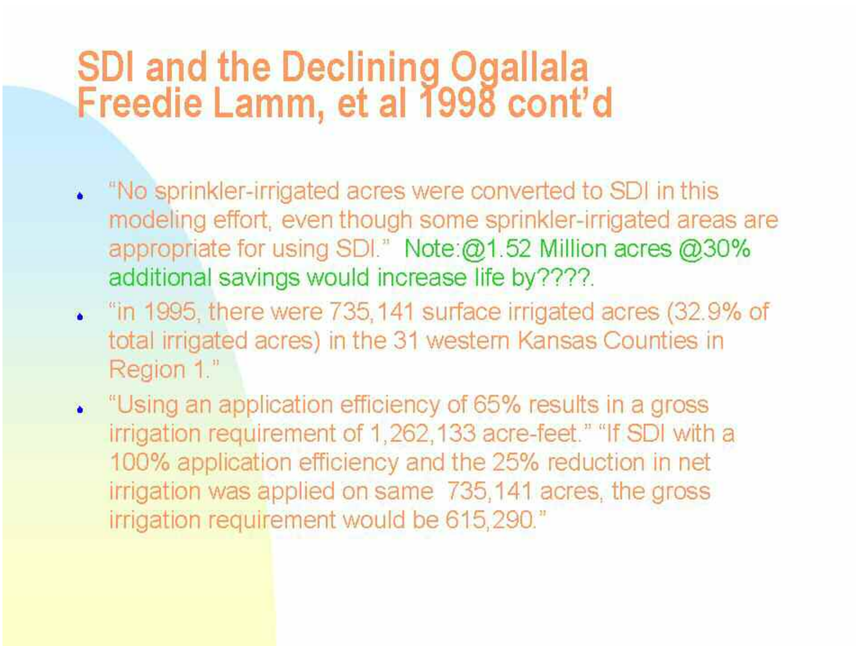
Could you imagine if we went in and fixed the furrow where it was the predominant form of irrigation? You would see a significant improvement in productivity.

One place they would extend the life of the aquifer over 100 years. It

gives us a lot of time to come up with alternatives, moving water from the Mississippi in flood stage, all kinds of things. That's basically what he came up with.

Then he looked at here's the real numbers. There were 735,000 irrigated acres which was about a third of the acres in western Kansas. Using that 65 percent he figured he'd need about 1.3 million acre feet of water. That's enough for about six million people, 5.5 million people. A fair amount of water.

If he applied a 25 percent reduction in net irrigation and assumed that we had no losses with the drip irrigation because it's underground and there's percolation, his irrigation requirement would have been cut in half, to 615,000 acre feet. That means they would have freed up enough water to last, the timeframe we talked about, or if it was in a surface situation he would have freed up enough water for another two or three million people. So the extension of that was very huge.



He also looked at how much each extra acre inch of water would produce, and that's 10 to 20 bushels of corn. In most cases that's a five to ten percent increase in yield for every extra acre inch you put on. That's a huge number.

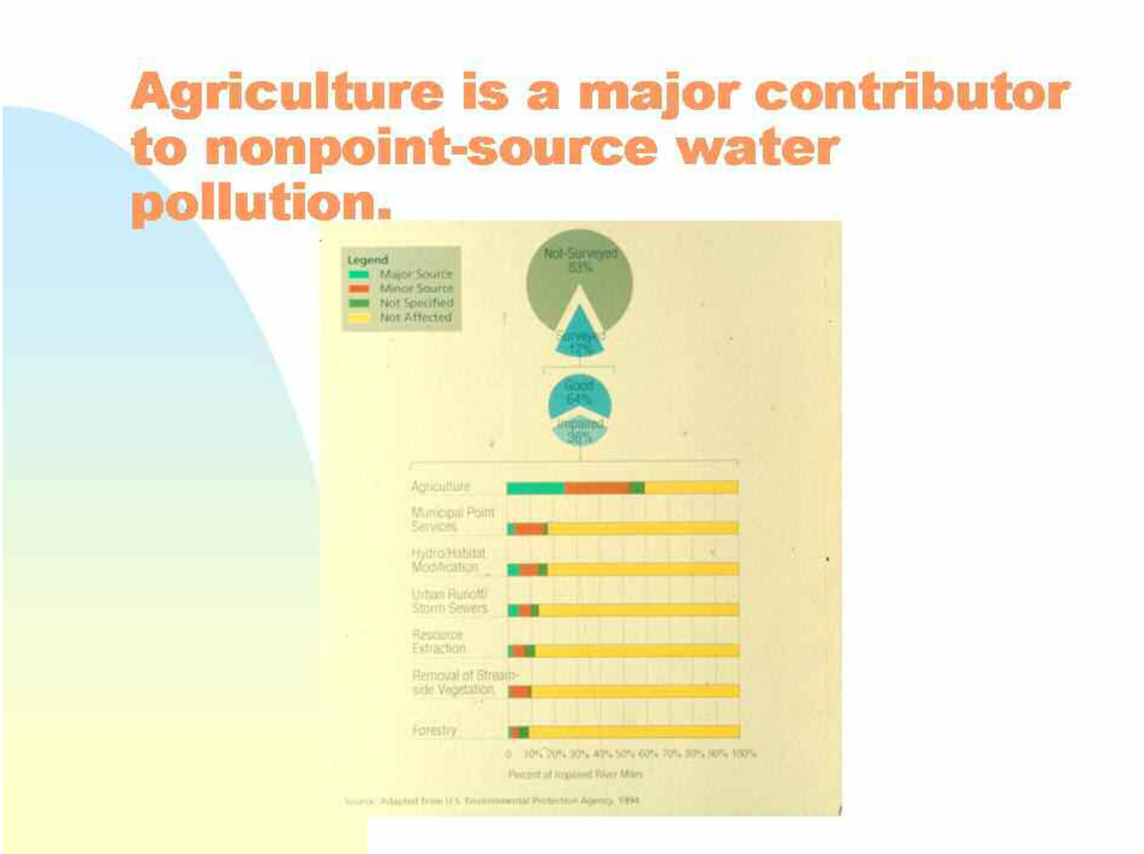
He looked at 235 corn which last year was up to three. It would range anywhere from 182 to 365 million dollars in gross revenues.

He said if we converted that 735,000 acres at $540 an acre, which when he did this in 1998 that was about the price, I'm going to show you some technology today we can do that and we can do it very quickly, it would require $400 million. So you're talking about a payback to extend the life of that aquifer about equal to what the revenue would be generated in one year. It's a huge, huge, huge thing to think about. Irrigated, the gross revenues from all of agriculture in the state of Kansas are $9 billion. So to spend $400,000 to maintain a significant portion of that $9 billion plus in revenues is probably a pretty smart investment.

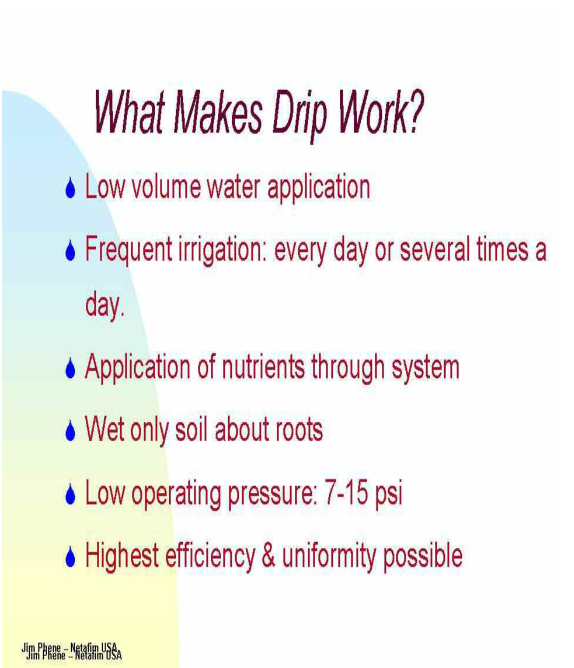
Erik Peterson: Jim, I'm going to ask that you wrap up here. I want to make sure we have time for discussion with the whole panel.

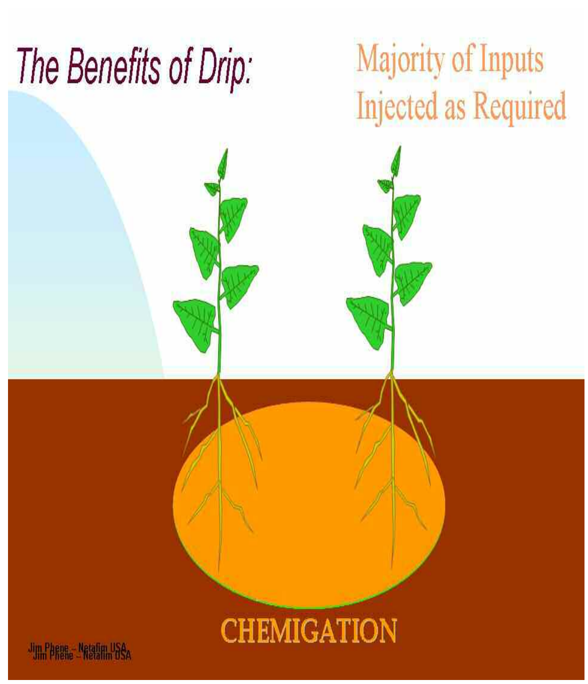
Jim Phene: I told you, that's how it always works.

Water quality, I'll slip through here. Agriculture is the major non-point source. You can



look at erosion, similar to all the other major watersheds in the world. Nitrate, phosphates, pesticide pollution, and you've got this huge hypoxic zone here. So if we eliminate runoff, we eliminate all these issues here. We eliminate a lot of extra chemicals, you eliminate a lot of herbicides, we reduce our chemical and fertilizer applications by 40 percent, we eliminate deep perc, we eliminate runoff which are the two major sources of contamination and also water loss. We have a lot less salt accumulations, a lot less disease, and our tractors work a lot better. For that instance, people have to walk through there and it's a long life system.

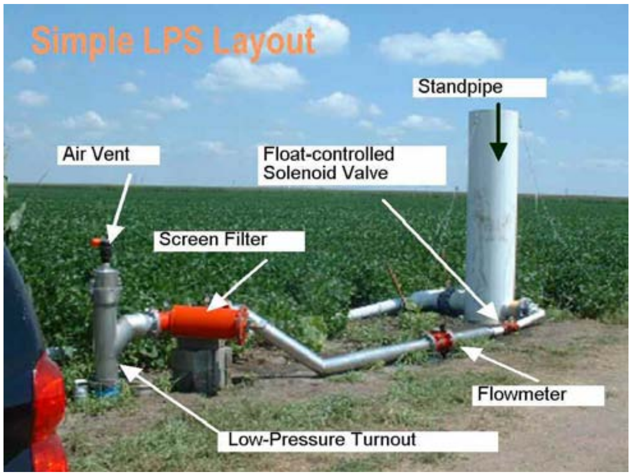




Basically what we're looking at with drip, if we look at vapor transport, we look at all these different places where water goes in a hydrological cycle, we have plants we have soil, we have precipitation irrigation in water that moves up. R and D which are runoff and deep percolation are the two major losses that get eliminated by drip.

So if we look at it in terms of the major issues throughout the world at lower salt accumulation, lowers evaporative losses, a lot of flexibility, mitigates surface runoff, deep percolation, dry soil surface, increased herbicide, erosion, provides the highest efficiency available.

I'll show you these last couple of slides and then I'm done.



This is a low pressure system that's used, you can run it with a 55 gallon drum or a few hundred gallon tank, and you could feed a village with that. Fresh vegetables.

We also have this set up for regular fields, a quarter mile long. This is one up at University of Nebraska. This thing runs on less than ten feet a head. We're talking about an investment at the retail level of about $500 an acre. There are places now where they're being either told to turn their water off or they're no longer allowed to drill or they're no longer allowed to use the kind of acre feet that they had in the past -- 18 inches, two feet, three feet. Now they're being told they can use 6 to 12 inches of water.

These guys right here grew 225 bushel corn with half the water you would normally grow. There's what it looks like going in, that's what it looks like installed.

That's it.

Erik Peterson: Thank you.

[Applause].

Erik Peterson: I'd like to invite you to think about questions that we'd like to have this panel address. We've really seen a number of different pieces of the technology challenges that are there from the demand side in this last presentation on the agriculture to the supply side in the first presentation from Tom on different ideas about how supply can be significantly increased, to other things like major interdependencies with other elements of infrastructure, energy being a primary one. Finally, to ideas about the nature of what innovation really is and how it's a multidimensional process. It's not just technical performance, it's barriers to use, it's

understanding how to fit a technology to a local economy, and how to engage in in-country institutions.

Across that diversity of things I would like to invite questions from the audience relative to this whole question of how you drive innovation and what innovation should look like given the scale.

I think one of the other comments that was of particular interest, I think it was in the first presentation, and we've talked certainly in the first workshop about the enormous scale of the issues that we're trying to tackle. So some of the questions about how it is that we do it at that scale.

I'd like to open the floor for questions to the panel.

Question: Robert Ames with Johns Hopkins University.

I wanted to ask Susan, in the programs in your projects that you were doing, how did you deal with questions of uptake on the use of the technologies, and sustained use of those technologies? We know a lot of times in water treatment, in studies that people are working with them over a six month period or a year that they continue to use them after that kind of oversight is over, a lot of times the takeup is not sustained in the use. How did some of those technologies that you're working on, some of the filter ones and the newer ones that you were talking about have a, how do they deal with those issues?

Susan Murcott: I mentioned that our own work is six years, six to seven years on household treatment. A lot of the work we've done so far has been at the R&D level of what's working, what's not working, and not just at the technical side but also what's socially acceptable, what's economic and so forth.

As far as scale-up, our own experience is still quite limited. The example that I closed with at the end of the canshan arsenic filter is a system that we are responsible for implementing and there are 2,000 units reaching 15,000 people.

We are extremely interested in sustained use, just exactly the point you're getting to. We're fortunate in that the flow rate is such in the system, this canshan system, that users aren't getting turned off to it because it's just giving .2 liters per hour like a lot of the candle filters do. Just not enough water.

Similarly I mentioned that there were some issues with the SODIS from the people that we talk to, and I think that Rochelle can talk to that as well perhaps informally after we break, to how we can get that kind of acceptability.

You're asking a big question and I haven't begun to sort of answer it, but those are some of the dimensions.

Erik Peterson: Thank you.

I'd like to expand that question and ask Tom Hinkebein, our first panelist sort of the equivalent question but in the realm of advanced technology. In general, water industry is a relatively low risk, low margin type of industry and that's exacerbated in developing countries. When you're talking about advanced technologies there are barriers to entry for utilization as well as the challenge perhaps of how it is you sustain those in settings in which are not developed countries. Any thoughts on that?

Tom Hinkebein: Let me start with a portrayal of what it's like in this country. In the U.S. we live in an environment that is very risk averse. The water industry is one where the economic environment, the physical environment of water utilities are developed in, they have to fund new ideas or new projects with funds that are available and those funds typically come from bond kind of environments. You can't mix a high risk kind of technology with a low risk environment where the actual lender expects a rate of return that's almost guaranteed. Guaranteed means no risk.

In other countries there are actually some relief from some of that because the needs are greater in a lot of countries, particularly what we have seen in Caribbean countries. They are willing to take higher risk because the need is greater. Island countries typically don't have any other resources other than the ones that they can get by employing some advanced technologies.

As a consequence I see a trend developing, and that trend is people with a greater need are willing to assume slightly higher risk when it comes to employing new technologies. So that may well be an avenue to get new technologies into the world marketplace as well, by going to places where the need is greater and where people are willing to assume slightly higher risks.

The bottom line on all of this is that there needs to be some pretty fair assurances that the technology is actually going to work. The question is will those assurances meet the litmus test of financial institutions or engineering organizations, those that have different sets of acceptance for risk.

In essence, the important part of the question is that you need to start getting new technologies into the marketplace where they can actually have experience being tested and used in the environment where they're going to be used, and then you've got some opportunity to expand that.

Question: Jeff Albert from AAAS. Actually, I had an additional question for Tom while we're on the subject of both membranes and of social acceptance.

I was wondering how much of the work that's being done either with your group in Sandia or generally within the community is focusing on the potential for membranes in the reclamation of wastewater, potentially to potable levels. So in terms of social acceptability, that's what's frequently kind of put forth as the biggest obstacle, not the technical or the economic.

Then the second question if you have time, I was just curious about what you might be able to say about cost reduction on a unit basis for water production on using RO based on these new potential innovations. The number I guess we hear from the Middle East with the new Israeli facilities are 50 cents a cubic meter. I'm just curious if you can speak to how much lower we can expect that to go.

Tom Hinkebein: In terms of social acceptance, as many of you are aware, water reuse projects are supplying water to industrial concerns and meeting far higher levels of purity than are typically demanded by the actual municipal user of water.

The thing that's interesting about it, it is strongly dependent on location. In the west part of the United States, areas like California, my surmise is we will not see it in my lifetime or anybody else's at this table in terms of having acceptance of water reuse for potable applications.

What's intriguing about that is one, I grew up along the Ohio River and upstream from us was Cincinnati and Pittsburgh and they took water out of the Ohio and passed their waste back into the Ohio River and did that city after city as you go down that stream. People don't think about it in that environment. They accept it as part of what is typically done.

It is a social problem. It is one where we will probably have continued acceptance in places where people don't think about it too strongly, in areas where water resources are more limited you find a different opinion.

So in answer to the social acceptance of it, I don't know that I know the answer, but I do observe this huge difference from one part of the world to another.

In terms of cost reductions expected for membrane types of treatment systems, the 50 cents per cubic meter cost is currently our standard. Recently we met with representatives of the Dow Chemical Company film tech. GE has now put themselves into the middle of the fray, if you will, by purchasing Osmonics and [BETS]. They claim to have 20 percent reductions in cost in the pipeline. So within the amount of time that it takes to get acceptance of technologies I think we'll see a 20 percent reduction from that 50 cent per cubic meter kind of goal.

The kinds of technology advances that I was alluding to in my presentation I think are also possible and I think we can see a 50 to 80 percent reduction from that 50 percent number with the advent of some of the newer technologies. I firmly believe those are reasonable and they're certainly not limited by any of the basic science, so I think that those are possible.

Question: Craig Shiffries, National Council for Science and the Environment.

At the World Water Forum in Kyoto last year, or in 2003, many delegates from developing countries initially at least expressed opposition to recommendations in the Ministerial Declaration related to further investments in R&D related to water technologies. When asked about the nature of their opposition there were two general reasons -- one was research and development was an excuse for inaction; and the other was that research and development wouldn't meet their needs.

I think we could get past the excuse for inaction pretty quickly, but then the obvious question is what are your research and development needs? They said three things. First, they wanted it to be affordable; second, culturally acceptable; and third, point of use technologies.

So I'm wondering to what extent U.S. R&D efforts, federally funded, are devoted to those goals? Most of Susan's work, it appeared at least, was funded by foundations as opposed to federal agencies. Could you comment on --

Susan Murcott: I'd love to comment on that one. [Laughter].

I have a slide that I may or may not show in Part two this afternoon of my professor, he's 80 years old, under whom I've studied. He's been at MIT for 50 years. He's an emeritus professor. It was only in his retirement in his 60s that he got into, with me, wastewater treatment in megacities of the developing world. It's not a way to make your career. It's something that you can do if you're an emeritus professor, a retired professor, or if you're a fool like myself. If you're sort of enough on the fringe of the institution that you are just dedicated to the work, but you're not going to get -- I'm a non-tenured faculty at MIT. I'm not in the tenure route.

There are several interesting trends. One is that I get invited to university engineering departments to speak on a regular basis in the last several years. There is an enormous energy and interest in the work that I and my teams have done, and also work like Amy Smith is doing on technologies generally for developing world, not just water technologies. But engineering education in water and wastewater treatment is all focused toward centralized systems, not toward decentralized systems, and there's no federal research money for this. There has not been.

So if there could be even small amounts of money that could go to support this work it would be enormously relieving to those of us like myself who are trying to move this agenda forward. There is a lot of interest in other universities too, but it needs this kind of a forum, and then to move that forward into legislation to see that's happening.

What's interesting is how much enthusiasm and interest there is at the student level for this kind of work. I get so many students knocking down my door and around the countries, I see this happening as well.

When I started this program in Nepal in 1998 and asked to introduce it into the MIT system, the response was we don't do that. We don't do low tech appropriate technologies at MIT and there won't be any interest in it. That year in the water engineering masters program there were 20 students. Sixteen of them signed up for the project. Some of the higher powers that be scratched their heads and said well maybe it's a funny year, but the next year it was the same and the next year it was the same.

I just came back from Kenya with 17 students in my team. It's the biggest team yet. So there's definitely a trend that's coming from the students towards wanting to do this work, but there is absolutely no funding for this work.

I work on pennies, honestly. And the reason, too, that I work on household systems is because they're so inexpensive. Basically it's a Third World effort that I'm engaged in with Third World funding for it.

Erik Peterson: With that comment I want to close the session, but I do want to raise one key observation and that is in the effort around global water futures we've been focusing on the combination of technology and policy, and in fact the opportunity to address the kind of question that you have raised sits in the policy portion of things. The world is changing and there are opportunities. Senator Frist's bill is one example. The bill that Senator Domenici is working on is a second. And that's essentially what this whole forum is about, is thinking about what on the policy side we need to do in order to make those technology options possible.

With that challenge, we'll end this panel and take a break for about five or ten minutes.

(Pause)