CIRCLE Graduate South Asia Conference—October 6, 2023: Keynote “Water Sustainability for Everyone? The Implications for Climate Change,” By Ed McBean

Vinay Kanetkar:

Hi, it gives me a great honor and pleasure welcoming Ed McBean, who is currently the Guelph Research Leadership Chair and Professor of Water Security. He received his BSc from UBC, PhD from MIT.

He has spent number of years as a faculty member at the University of Waterloo followed by decade of Vice President at major engineering company and then he again joined the university as tier one professor. His research interest is in using statistical interpretation of data aid and transport of chemicals and pathogens and environment and risk assessment management determine how issues of water supply risk may arise. Ed, floor is yours.

Ed McBean:

Thank you very much and greetings to everyone. In some cases, good morning and other cases good evening. At this point, then, I'll just share my screen and hopefully this will work. Are you now seeing the screen? Yes. OK. Excellent. OK.

Well, greetings everyone. What I'm going to talk about today is water sustainability for everyone, the implications of climate change and well, some other issues as well. But regardless, this is what we'll be talking about. So, well, there we go. We can't afford to waste a drop.

As I use this, this is the mantra that I typically follow because we are in dire straits throughout the world and the world's future really depends on it. However, what I'm going to do is have two-part presentation. One will be the impact of water demands on water security and I will be emphasizing the impacts on groundwater withdrawals, particularly because they're so relevant to India.

I will then talk a little bit about climate change and the implications of loss of glaciers, which is really very relevant to your portion of the world as well as ours, meaning in Canada. And part two will be water for rural areas. So, we have been working very diligently on developing some water technologies for water treatment for the impoverished people and villages, that type of thing. And then sum it up with some conclusions.

OK, so what we have is the impact of water demands on water security. Well, everyone needs and demands safe water as a basic human right. But here is a pattern that is pretty much obvious to everyone, but it shows the progression of numbers of people on the earth over the last 2000 years approximately. And what you can see is the escalating amounts that are current and what is the expectation by even 2050 of 9.1 billion people.

The challenge for that is that the rate of growth of water use to attain this level that we're currently at over the last 50 years has tripled where the population of the people has only doubled. In other words, much more water has been used per capita than previously. Obviously, that's partly a function of our ability to do that, but it is really problematic because there is not sufficient water to repeat that, but we'll see that as we get there. OK.

So, just quickly, global view of water demands, well over the past 55 years, the population has increased from 3 billion to 8 billion current. The demand for water will continue to increase dramatically because we need food, which needs irrigation and so many other things from day-to-day. So, this is well, dramatic, but it's not going to be possible to do again.

So, in other words, we've got to find ways to be more efficient than we have been for the last 50 years. Demands for water are increasing, mega cities are expanding. And by big cities I'm referring to 10 million people being in the city. There are forty of those right now, but the expectation is by 2050, 70% of the world's population will be in cities.

So, these are a huge amount of urbanization and increase in the number of mega cities. And all of which demand a great deal of water given the coastline enormous concerns also with rising sea levels. In other words, the oncoming storms to the shorelines are causing huge issues around the world and that includes India, but it also includes the United States and Canada because we get clobbered by them as well. So however, let's now look at the considering the situation 1960s in India, because this was a very important period of time.

At that time there were huge issues of hunger, inadequate foodstuffs, there was a need for irrigation. The 1966 drought, as what I was referring to, drove India into a—in quotation marks— 'ship-to-mouth' existence. There was not the ability to grow sufficient food for the population. Hungry mouths, they could be only filled by food aid, which reached a record 10 million tons within 1966.

Foreign experts, they opined that India could never feed itself. The extent of hunger was extreme in the 1960s and I recall seeing pictures of the devastation that was caused, you know was rising at that time. However, fortunately, the invention of tube wells was extremely important. And what I mean by tube wells is the ability to remove groundwater, pump it to the surface and then use it for irrigation.

The result has been and looking at the top quotation there, the development in groundwater withdrawal and selected communities. And what you see is India has rocketed from the period of roughly 1966 to well as far as the diagram goes but continue. In other words, India was able to develop and implement groundwater withdrawal to massive amounts that was allowed by irrigation pumps. They were electric, they were oil engines and so on.

And the result was that they were able to bring the necessary water as needed to the situation to irrigate the crops. The challenge is it's an incredible impact because the tube wells for irrigation it has. India now has the highest groundwater usage in the world, enormous 1,000,000 tube wells in 1960, 20.3 million tube wells in 2005 and this has continued to escalate.

Groundwater supplies now supplies 45% of the irrigation requirements in India. Well, what are the downsides to that? Well, the implications include, first of all, you've got to have a lot more energy to pump that water to the surface because now, what's happening is groundwater levels are falling, which means more energy is needed to bring that water to the point of irrigation.

Groundwater levels are declining because the expansion, the replenishment of groundwater is not commensurate or the same as the demands that are being placed on it. Water quality concerns. As you get deeper into the subsoil environment, the quality deteriorates. Land subsidence hurts.

Think of a situation of a sponge with water in it, and if you remove the water and have a weight on the top of the sponge, what happens is the sponge contracts. In other words, when you remove the water, land subsides. Now that is an unfortunate thing because now what happens is that never will again have water in it. In other words, the subsidence removes the ability to store water at those kinds of depths. Depletion of groundwater as a result.

Alright, well, let's keep that in mind as we proceed along. But as you can see here, this is a listing of a series of individual countries and it's the area in millions of hectares and it represents the graph shows the area underground water irrigation. So, you can see that massive amount in India, much bigger than the United States and succeeding over the various listed countries as indicated.

Excuse me. So, what's the current situation in India? Well, the groundwater was of enormous value and needing food for starvation in the 1960s, but it has the highest groundwater usage in the world. The tube wells, they were dramatic in terms of their ability to supply the water for irrigation and grow the foodstuffs needed.

But overpumping is causing aquifers in India to drop by 1 to 3 meters annually. Gujarat, the groundwater levels 50 years ago were 10 meters below ground surface. Now they're 500mm below ground surface. So, this is not a small change. This is depletion of the groundwater source. Karnataka, 20% of the tube wells are going dry every year. We'll come back to that in a second or two.

As a result, what we have is a situation where, as you can see, India in terms of the black portion there indicates the sustainable yield, 1995 is the gray, and it shows that there was more water being removed than is sustainable. And in 2025 the expectation at least, as indicated by that. I'm seeing something. Who can see this transcript recording? Well, I'll carry on and regardless. What you can see is the expectation of expanding the irrigation using groundwater is going to be extremely difficult.

The problem with groundwater is that it takes a very long time for the surficial water to fall and then migrate through the soil profile. So, groundwater, 110th of 1% is replaced each year. In other words, when you draw it out too quickly, it doesn't recover quickly. The residency time of some of that water is 1000 years. So, what's happening in terms of subsidence? Subsidence in India now exceeds coastal, absolute sea level rise by a factor of 10, for many coastal cities.

So, in other words, it's not really the coastal city issue as simply the fact that the water is rising, although the storms will bring water onto the surface, but it's the fact that the there's just been so much removal and so much subsidence that that's a challenge in terms of depletion of the groundwater.

Every meter drop in groundwater levels translates to approximately 3.3 centimeters of subsidence that will not be recovered. And I'm emphasizing that. 21 major cities in India are poised to run out of groundwater very soon. That includes New Delhi, Bengaluru, Chennai, Hyderabad, and I didn't list them all, but this is dramatic in terms of the availability of groundwater is a huge, huge issue.

Lucknow is undergoing massive subsidence. Kolkata is subsiding at 13.5mm per year. As a result, they're having to redrill the wells, you know, every couple of years because of the subsidence and Karnataka, 20% of the wells are going dry every year and must be redrilled frequently. This is what happens in terms of just going to get something off the screen here.

What happens is you get to subsidence, but it's differential. And as a result, you can see this is the situation showing where the bridge has been deteriorated. It's now cracking. And so, the surface regime is definitely impacted by subsidence. Why is it not moving? There we are. Well, you're not alone in that. In other words, this is subsidence here and showing over the time history of approximately 1000 years. Sorry, 100 years.

Tokyo, they learned in about 1970 that they could not continue to withdraw groundwater, and instead, they've gone to provision of water by virtue of bringing it from the mountains. Much more difficult. Manila, Bangkok, Taipei, Osaka, etcetera. Particularly interesting one, important one, is Jakarta. Why is it not moving? Oh, here's the picture of West Java and here's Jakarta. What's happening now is the land has subsided so much that the rivers don't flow all the time.

In other words, they can only flow, rivers, when they are at low tide. In terms of the timing. As well, they've developed a very nice highway to the airport, but they can't use the highway because it's now flooded. So, subsidence in Arizona, subsidence in India, subsidence in Jakarta, it is all the situation that this is a serious, serious issue.

This one shows this simply, what's happening in terms of Arizona. This one is in San Joaquin Valley in California, and you can see the man standing beside the well, but it shows, as you can see, the progression of time frame there. This land has subsided by, you know, 70 feet, that type of thing. It's really huge in terms of the implications.

Here's a ground fissure resulting from an overdraft of groundwater in the North China Plain in Hebei province. But you can see the girl there is observing, Gee, this is subsidence that's on a very localized scale. Withdrawals around the world, they are limiting the extraction of more groundwater, depleting this as a source of water.

This is not a problem unique to India. It is very, very widespread. Well, OK, let's talk about climate change and the implications of loss of glaciers. You can see that the temperatures, and this is no surprise to anybody that's been keeping track of what's happening with climate change, what is a continuing increase of temperatures around the world. Each year, successively higher than the previous year and continuing.

So, let's now talk about specifics related to glaciers in the vicinity of India. There are about 90,000 glaciers in this region. They form the headwaters of the Indus, the Ganga or Ganges and Brahmaputra. They're used for agriculture, hydropower, water supply. So, in other words, it doesn't have to rain very much in the vicinity of the Indus River to actually still have water there because it's the melting of glaciers. Water is life, it is not just a 'nice to have', you must have water. You can only survive about 5 days without water.

So now we look here at the drainage patterns associated with the Indus, the Ganges or Ganga, and the Brahmaputra. You can see that the Indus is the primary for Pakistan, the Ganges is a primary for India, and then Bangladesh, which is shown down on the, well, basically the middle or Dhaka, that is a very important water body input from the Ganga.

Similarly, the Brahmaputra circles around from the northern side of the Himalayas and in turn then ultimately discharges into Dhaka. Developing countries in these catchments, they're using meltwater for agriculture, water supply, hydropower. The contribution of glaciers, however, varies in each basin.

We expect an 18.8% in the— I'm not sure how to say that, but Dudh Koshi catchment by 2100. This is a major tributary to the Ganga. Expectation of an 80.6% reduction in the Hunza catchment, which drains into the Indus basin. So, in other words, it is going to be dramatic for them in Pakistan.

So, if we look at the map now that shows Pakistan, India, so on, you can see how the water is, you know, relevant and coming from the southern side of the Himalayas, draining into India, which is the reason that you've got so much water available for irrigation. And you can also then see how important it is in terms of Bangladesh.

So, what's the impact on the Ganga? By 2060, we expect a reduction of 18% of the flows of the Ganga, and 20% reduction of flows in the Brahmaputra. Bangladesh is currently having trouble already, by having to frequently re-drill wells. Shortages are already occurring, what's happening in part is that there is diversion of water from the Ganga down to Kolkata.

No countries in the world are going to have more difficult issues ahead in terms of water than India, Pakistan and Bangladesh. Well, also, the Chinese government is considering taking the Brahmaputra where it's in Chinese territory and diverting it into the areas of the deserts in the western part of China. Well, that suggests that we've got a lot of problems, but it wasn't even limited to that. What about also the polar vortex effect? And you might say what is the polar vortex?

Well, what happens is vortices are responsible for the dramatic, short-term changes in the winter climate. What happens is in the northern area, northern pole, the air is being warmed because the ice on the Arctic Ocean is very shallow. It's only about two meters thick on average. As a result, it's warming. And then as a result, the strong jet stream that's implied by the left-hand diagram shows a weak jet stream on the right-hand diagram.

So, what happens is then the cold air moves south. What happened then, for example, is the southward shift of polar jet stream ended up in freak hailstorms in central and northern India. And this is about west of Delhi, in February and March in 2021, and destroyed their harvest. So, what does it all mean? Well, more very cold weather for short periods of time will intensify.

But, if it destroys the crop at one particular time, that crop will not necessarily recover. And they appear to be. They will intensify as the Arctic oceans tend to lose their surface ice cover. Will cause increasing challenges to southern areas, including India. So, the water issues are becoming profound at the global level. This is not an India problem, it's not a Canada problem. It is a universal, widespread going problem, and you can see why as a water security person, that's what I do for a living.

This is going to become profound at the global level. So, with that, let's now change to water for the rural areas. So, what I've tried to suggest in the part one, was India's got problems in terms of the availability of water. I'm sure you're— I don't know what cities you're from, but for the large cities, they are running out of water. But now what about the rural areas?

We have established that the availability of water in India will be very severe, in India, as we proceed in the future. This is one of the most important security issues that exist in the world and will intensify as time goes on. Two-thirds of the world's population currently suffers with water shortage. It's not, you know, a unique situation. It is very widespread. A child dies every three seconds from waterborne disease.

That, actually, to put that into context is the size of that, that level of three seconds per child death far exceeds the death rate of AIDS, wars and malaria combined. And malaria kills 600,000 people per year. So, this is a very severe problem in terms of the quality of the water which people have available in the non-urban, in other words the rural areas.

So, what did we say? Well, water can be fun but also can be challenging. It's life. So, what's happening with the escalation of water demands? Well, it is considered a basic human right. That access at all times to sufficient water and quality, quantity and quality to satisfy the needs. That is what is a basic human right.

However, when you're into sanitation and water treatment in low income countries, more than 2 billion people lack access to proper sanitation. And you can see why. 800 million people lack access to water safety. So over that 8 billion that we just passed, 800 million lack access to 'safe' water. So, this is a huge global problem. And you can see them here, they are lining up to access water, which is not very good quality, but it's the only water they have available.

Now. I've done quite a bit of work in Cambodia over the years, and these just show representative examples of the scenes in Cambodia just outside Phnom Penh, the capital. What you can see in the bottom left, that is where they are draining water from the rooftop down and then storing it in these large cylinders.

So that's a very wealthy family. They have three large cisterns that are available to store the water, but you can imagine also that birds poop on the on the roof which ends up in the water. Also, the opportunity to clean the vessels that remove the water from those cisterns. They're not very good quality, so therefore they are of poor quality.

You can see on the top, well the right, you can see a man carrying buckets of water substantial distances. In some cases, they do have quite a bit of water in Cambodia, but it's not a shortage, it's the quality that's the issue. And at the top you can see where there is a hand pump.

But when you think about— if you've been involved at all in pumping— the extraction of water from this hand pump, much of the vertical migration of water, if you can see how it's wet at the base of the hand pump, gets down to the area where it's then taken up to be water supplied from the depth if it's not constructed correctly, and many of them are not. So, this is a huge, huge challenge for them.

So however, I've been touting some difficult issues. How about some good news? How to provide safe water to people. Currently, approximately 5 major illnesses to children per year. Or just think of the devastation to the family. And this is just to children, but clearly adults also incur some illnesses as a result.

It's primarily bad for children because their intestinal vigour of their system is not yet developed. So, it's less impactful to adults, but it is still impactful, and is very impactful for children. So, let's look at what actually was invented and discovered, I guess we'll say, about 20 years ago. This is a treatment system. And what you can see in the middle of the left-hand column is the ceramic filter element.

The way this is created is to take rice husk, macerate it into small size, mix it with the clay, and form it into the shape of what looks like just a ceramic flowerpot. But it's not, because then we fire it and the firing removes the rice husk. Now you've got the porosity of the size that you want. That will allow water to move, but bacteria and protozoa will not be able to.

So, what you're doing then, is you add water, raw water, to the ceramic filter element. Then it filters through by this mechanism that I just referred to, where there's spaces within the clay, and subsequently into the receptacle tank, and ultimately can then be used as the spigot indicated on the bottom of that diagram. And the lid is simply just to keep things out.

So, the way this works is the raw water is poured into the top, into the ceramic filter element, and then at approximately 1 to 3 liters per hour, it is then lowered into or travels into the receptacle tank below. So that looks like a flowerpot, but it's not. And this is the result of that technology. The child is able to access the water for consumption. That can produce safe water. The problem is that it's difficult to create, and so I'll show you some other examples of it in a few minutes.

But basically, what happens is when the raw water is added, there is sediments, there is particulates from vegetation and so on, it tends to clog. So, you must remove the ceramic element, you must brush it and then get rid of that water because it's been contaminated. But the challenge is that they're very heavy. Older people cannot lift them, young people cannot lift them.

Even the, shall we say, robust people cannot lift them very well. They put them on the ground, which contaminates the outside of the filter as well. They may drop them just because they're heavy. They weigh about 8 kilograms, so this is quite heavy. As a result, this works, but it doesn't work very well. Let's look at a couple of other alternatives just to see where we're going with this concept.

This is the Lifestraw facility, and you can see the white at the top is a filter system to try to remove what they can and then it goes into, and I'm not sure whether you can see my cursor or not, but basically it comes out this way, and then this is where the water is actually then collected. And this is an interesting technology.

It's really quite nice, in that it has attributes that are highly desirable. The challenge, it's expensive. It's about $175 US, so I'm not sure how many. Anyway, $135 US. So, it's expensive. People cannot afford that. So, what have we been doing in in Canada, in particular in Guelph? This is the best technology that's currently available in terms of performance.

What you see is a large vessel, and we'll see better pictures of this in a minute, but the raw water is placed into a very large tank, perhaps a 50 gallons type of tank. What happens then is there's migration down and passage through to infiltrate or pass through this ceramic filter, which is here and also on the other side.

So, in other words, the PVC pipe has been cut off into sections that are about 3 inches long, so 6 centimeters long, and as a result you can get filtration on both sides of the water is coming down and travels through into this vessel and subsequently, then travels out here to the point of having filtered water provided. That's what it looks like when you then see it as it really is, as opposed to a schematic drawing.

But you can see the large vessel only needs to be filled once or once every day, or once every two days, to provide the sufficient water for a family. It's not for a village, it's simply for a family, and can deliver the water of quality needed to remove the bacteria and the protozoa. And actually, it removes a lot of the viruses as well because the viruses get eaten by the basically the growth of the activities on the ceramic filter and in turn then remove the viruses as well.

So, what does it all look like? Well, you saw the diagram on the top right as what was the situation is to the configuration with a clean out spoke, I guess I forgot to mention that. But the clean out spoke just indicates that occasionally you have to wash it out to get rid of the sediments that are collected at the bottom of the tank.

But what you see on the bottom left, that is a testing chamber where we use this to test different designs in terms of you know the size of the maceration of the rice husk and different configurations and so on. And we're testing the turbidity, the rate at which it it will tend to clog their pores.

But regardless, what happens is that water is then able to be used, and it is now safe water. And safe, I mean does not need any chemicals, but it will give you 99.9% removal of bacteria and protozoa, which is considered that any rational person would be quite happy to drink that water.

So that has been profound, and we've been working on that for more than 10 years. Different designs and configurations, but it is now in the testing situation, in the field testing, to make sure that people can use it. There's no chemical addition. It is simply a filtration effect with a biofilm that grows, and we'll remove that.

And that's been proven, and it can prove it can provide water at the rate of 1 to 3 liters per hour and perhaps for six years in duration. So, this is something that is, hey, that's really good. It only costs about $25. It's not a huge expense. It just feeds them. So, what actually happens then? Well, actually let's just say that for example, the ceramic filter deteriorates over time.

Well, you can make those in the systems that are usually available in communities, remote communities, because you can use the device, the oven which is used to make flowerpots and vessels and so on. Now you can create the ceramic filter, fire it in the village and then have it fixed not by sending it back to some, you know expensive location.

This is something now that can be done at the village level. Anyway, that's the nature of it in a nutshell. And one of the aspects that we really hope will no longer be needed is precisely this. This is the situation where the young females are taking significant parts of the day to try to find firewood to boil the water.

Well, we don't need to boil the water, it is removed simply by ambient temperatures and filtration effect and biofilm effect. Also, the water only has to be replaced once per day or once every two days, depending on the size of the family, and it will function in that manner. So, that's good news.

So, where are we in conclusions? Well, where is the water going to come from to grow crops? Groundwater. It's in serious trouble. The availability is highly troublesome. I really don't have an easy solution for that. Infiltration from densely populated cities. Well, what happens is they want to get rid of the water as quickly as possible. That means there's less replenishment of the groundwater. Surface storage, that's a huge issue because it needs such spatial size as well as costs.

Countries such as India, they cannot rely on continued availability of groundwater. Subsidence, it's creating major issues with land uses, and as I showed you, an example of what I could have showed you many more, unfortunately, but broken bridges. Climate change, it's melting the glaciers and glacier depletion is intensifying. All that means is that future availability of such water will be declining.

And you know, as I mentioned there in terms of the Indus, the Ganga and the Brahmaputra, there will be less water in the future because of the situation. Diversions of water from rivers is already seriously impacting water availability for downstream countries. So, India is impacting Bangladesh by diversions of the Ganga down to Kolkata. Brahmaputra may be redirected to China. India may be redirecting parts of the Indus flows which are resident in India, not to Pakistan, but to the northern regions, northwestern regions of India.

Finally, some good news. Well, we do have now some low-tech ideas on how to develop and provide safe water for rural families at levels that they can afford. It's inexpensive and robust technology, just pretty tough to break it. They can be repaired without sending it back to developed country for fixing. So, unfortunately, I am always concerned we won't run out of issues to address.

But ultimately, some projections suggest that up to half of the world's population could be living in water scarcity by 2100 AD. So that's only 77 years away. Water security and climate change, we got to recognize those and deal with them and do the best we can do with that. So, thank you for your attention. That's why I started out with this mantra: Don't let a drop go to waste. And open the floor to any questions?

Vinay Kanetkar:

Thank you, Ed. It was really eye opening, or maybe watery topic, but I think it was very well presented. I'm not aware of all the issues that you raised, but I think it's a very complicated issue for sure. I have a question here.

Ed McBean:

I'm just trying to get rid of the litter that's on my screen, anyway.

Vinay Kanetkar:

I mean, I also concur with you that the communicating to the public about how severe and challenging the water issues are, is really, very important. And I just don't see people are willing to accept this idea that there is actually a water shortage, and we should be taking care of every drop.

I concur with you on that one. On the other side, I've done some of my own research and people just don't get this idea that tap water, most times, is reasonably good quality compared to the bottled water, which is often time we spend 6 or 8 or 10 times. And maybe we should be investing that money into the tap water rather than in the bottled water.

Ed McBean:

Well, that's an interesting question you raised, and that's a very difficult one. But when you have the tap water, which cannot be distributed throughout the entire community, what happens is they will shut the water off and make it available only on Tuesdays, and then deliver it to other portions on Wednesday, Thursday, and so on. The challenge is, when you decrease the pressure in the pipe, then the ingressive ambient water which is contaminated or at least could be contaminated, becomes a real issue.

So, it's a very difficult situation. And as I say, it's this is not a problem unique to India. This is a problem everywhere I go, virtually, you know Argentina, they've actually had to cut off significant portions of the population of Buenos Aires. They're a big city— because they simply do not have enough water to even do it on one day.

Those poor people are now having to do the same thing that was shown in Cambodia, with the person carrying the water by the buckets. There's a question in the chat box here. You talked about technology for small scale. Can this be done in the industrial scale where water is needed?

There are more efficient ways to do it for the citywide situation, where the focus and what I was referring to, is more for the village. Where you know, there's a 1000 people or whatever in the village, but not huge. If you're into a situation like Coimbatore or something like that or Chennai, you can't do it that way.

It's too slow. And there are other ways to do it, it just does cost money, but you also have to know the water available to actually do that. And I know that Chennai has been really challenged as of late and I don't know the other ones as well. But anyway, this is not a not an easy problem.

Vinay Kanetkar:

Yeah, thank you. Any other question from the audience?

Ed McBean:

Just while we're waiting, I can concur that you're all probably a little bit 'Oh my, this is serious.' I teach courses on risk assessment at my university, and about halfway through the course the students are saying, 'Professor, you're scaring the hell out of me.' And they said, yes, I'm sorry, but this is reality. We have a huge, huge problem. And then yeah, I wish I had an easy answer, but there isn't. Doesn't mean we can't solve some of them, but it is challenging.

Vinay Kanetkar:

I want to take this opportunity to thank you, and I know you have to run for the class. So, I will let the session close, and I hope we move on to the next part of our program. Thank you very much for coming.

Ed McBean:

Thank you. It's been a pleasure.

[End of transcript]