Yellow Quill's Drinking Water
Part 3: A Solution Beyond Everybody's Dreams

By Dr. Hans Peterson

In June 2002, everybody agreed on one thing: resolving Yellow Quill's water woes would need some heavy artillery. I moved to Yellow Quill and set up two 48-foot trailers. One was for water piloting, with the second one for housing a laboratory and accommodation at the well head some 13 kilometres from the Yellow Quill community.

Has Anybody Encountered Bad Smelling Water?

We moved the trailers in early July 2002 and it was hot during the first several days at Yellow Quill. The first thing I noticed after the water was hooked up to the piloting trailer was that it smelled bad; it actually reeked. This water was straight from the well. I proceeded to take a shower the same day the well was hooked up. The shower was in the same trailer as all the treatment units that we were using. Coming out of that shower I made myself a promise to have fixed the smell of the water before I had my next shower.

To Drink or not to Drink the tap water

Have you ever thought about that? Most of the

Inside the piloting trailer SUBMITTED PHOTO

"advisors" coming to First Nations communities don't stay long enough to drink the water or take a shower. This is so for Indian Affairs, Tribal Councils, engineering company representatives and Project Management Team (PMT) members from outside the community. Would they accept some of the treated water quality that First Nations communities have to live with? Not likely. Many of these representatives bring bottled water just in case. But, I made the Yellow Quill well site my home for at least 6 months. In the end, wrestling Yellow Quill's water problem to the ground would take a lot longer than that and I stayed for a total of *22 months*. But, it took only a few days before I had sorted out the smell in the water and I could have showers without coming out reeking bad. I know Indian Affairs had listed this groundwater as "untreatable," but the first objective, get rid of the smell, it was accomplished in three days. Small victory.

Safe Drinking Water from every Tap

Later, I realized that bringing bottled water when visiting a First Nations community may not be such a bad idea. Because in some such communities safe drinking water at every tap seems to be a foreign concept and community members have to pick up "safe drinking water" from a small Reverse Osmosis unit at one tap somewhere in their own community. This tap is often at the water treatment plant where the RO retreats the water that is distributed to the community. This water is strictly for drinking and community members typically fill 19 L bottles to take back home. When a community gets a water treatment system that cannot perform and community members are asked to pick up drinking water at this one tap, is that an admission that household taps give community members water that they cannot drink? In 2015 "safe drinking water at every tap" became the Safe Drinking Water Team's call for action to resolve First Nations drinking water issues (www.safedrinkingwaterteam.org) in reserves across Canada.

The Dirty Dozen

But, maybe we should start by trying to define what is wrong with Saskatchewan groundwater? When I give presentations I outline 13 problems although several more can be easily added. Additional problems include the growth of disease-causing microbes in community and house distribution systems. But, let's ignore that and start with the 13 problems that I have summarized below. BF stands for *Bacterial Food* and is possibly the largest of all problems that we have to contend with in Saskatchewan water sources. The 13 problems are all too high in our raw water sources. Most of these compounds except where noted don't smell and they don't give the water a taste although some may taste one or two of those compounds:

1. Total Dissolved Solids (TDS), or conductivity (conductivity times a number = TDS), high TDS tastes salty
2. Calcium
3. Magnesium
4. Hardness, Calcium + Magnesium
5. Sulphate, a laxative
6. Hydrogen sulphide, rotten egg smell, BF
7. Methane, no smell, BF
8. Iron, anaerobic no colour, aerobic brownish-black, stains clothes, sinks and toilets etc., BF
9. Manganese, anaerobic no colour, aerobic brownish-black, stains clothes, sinks and toilets etc., BF. At levels above 0.5 mg/L manganese is toxic (Canadian Guideline is 0.05 mg/L, aesthetic guideline)
10. Ammonium, interferes with chlorination, BF
11. Refractive dissolved organics, reacts with chlorine lessens disinfection effectiveness and forms chlorination by-products like trihalomethanes, can form slime
12. Bioavailable dissolved organics, BF, see Point 11
13. Arsenic, can cause cancer and other illnesses, BF

To be able to get close to safe drinking water we need to start counting to 13, and we need to use water treatment technologies that allow us to do that.

Biological Water Treatment

I had great hopes for biological treatment. When I was the head of Saskatchewan Research Council's Water Quality Section I had several Master students from the University of Saskatchewan working on drinking water treatment. I was also a research associate with Napier University in Edinburgh, Scotland and I supervised doctorate students from Napier. One of those students worked on *biological treatment* and we published several academic papers. She is now Dr. Joanne Sketchell and works for SaskWater. Being a curious scientist I had followed developments in biological treatment globally. At Yellow Quill several of the pilot treatment processes that we set up used biological treatment in one form or another.

As I described in previous *Tribune* issues, none of the conventional treatment methods that we tried at Yellow Quill worked. Not even some drastic oxidation methods (ozone, UV) were able to reign in the Yellow Quill groundwater. But, we tried. Later work at Pasqua and Gordon's showed that conventional technologies didn't work there either. This has not stopped engineering companies from designing and building them! The only processes that showed some promise at Yellow Quill were the different forms of biological treatment: with the unconventional idea of using bacteria to clean up the water. We truly had to move from chemistry to biology at Yellow Quill.

One Norwegian and one Swede come to our rescue

A representative for one promising biological filtration material, Filtralite, thought what we were doing was interesting enough to fly from Oslo in Norway to come and surprise me by coming to Yellow Quill with Dan Hogan, senior engineer for the project. This was the Norwegian in this plot, Ole Jacob Sortehaug. Ole had worked around the globe on water treatment issues and he stayed with me at Yellow Quill for one week trying to convey as much information as he could, how to carry out different experiments etc. This was invaluable and some 12 months later Filtralite became the heart of the process that we ended up developing. Supporting Ole was Lars Christensson, a Swede that was stationed in Oslo and the head of the Filtralite Division. Saint-Gobain, a very large European company, currently manufactures Filtralite. Ole and Lars don't work with Filtralite anymore, but both remain friends of mine.

Ole Jacob Sortehaug SUBMITTED PHOTO

Lars Christensson SUBMITTED PHOTO

What is Biological Treatment of Water?

In biological treatment biofilm-forming bacteria are used to treat the water. Trillions of such bacteria are required. These bacteria attach themselves with a "glue" to the material that we have in a series of three vessels. Each vessel or filter tank contains totally different "consortia" of bacteria.

A consortium of bacteria is a large number of different bacterial species that work together to purify the water. In the IBROM process we estimate that there is more than 30 different types of bacteria in each filter. Selecting the right organisms to purify the water is a key element of effective biological treatment. We cannot add any bacteria, so for each water source we need to tease out the right ones. I am a biologist/microbiologist and identifying what bacteria prefer has been a tremendous advantage in the IBROM development.

Early attempts to carry out biological filtration used sand with Indian Affairs supporting some slow-sand filtration applications on First Nations water in Canada. Sand, however, is a very inefficient material to attach bacteria to and most water treatment plants would select better materials. The most common material is Granular Activated Carbon (GAC), but it has a lot of problems associated with it and while we tested it I was hoping to find a better material.

Filtralite shines

By the time we had done extensive tests with Filtralite a very large European water treatment company declared that it was the best water filtration material in the world and proceeded to replace sand with Filtralite in water treatment plants serving millions of people in Europe including the City of London. I was pretty much convinced as well that it would be very difficult to beat Filtralite and further pilot testing and full-scale testing has borne this out.

So, what is Filtralite? It is a ceramic material that looks a bit like coffee grounds. It also comes in various sizes just like coffee. But, Filtralite is made from a natural clay material that is found in the ground just north of Oslo, Norway. This clay is baked in huge ovens producing a ceramic material, which is then crushed to the required size. The company producing Filtralite carried out thousands of hours of research before Filtralite for water treatment became a reality. Below is a close-up photo of Filtralite granules before final crushing.

The Filtralite material is added into filter tanks and the water flows through the material providing food for bacteria 24 hours a day. We also make sure that the right Filtralite material is used and that each filter has the best conditions possible for the types of bacteria that we grow in the filters.

The key attributes of the Filtralite material is that it is inert and has low loss rates. A competing material, GAC literally crumbles with age releasing "fines" or debris breaking off from the GAC. This debris is loaded with bacteria. Another advantage of Filtralite is that it has uniformly-sized "rooms" for bacteria while other materials can have a mixture of rooms that are too small or too large. Think about it. Bacteria can only attach to the floor, walls and ceiling of the rooms. Compare a room that is concert hall-sized as opposed to hundreds of smaller rooms that have far greater area of surfaces for bacteria to attach to. The more bacteria we can grow, the better the biological treatment. That's why concert hall-sized rooms are simply too large.

In summary what counts is having the largest area (walls, ceilings and floors) where bacteria can attach. The larger the number of bacteria, the better the treatment. But, there is one restriction. Water needs to constantly flow across the bacteria to make them the virtual water purifiers they are. If your rooms are tiny closets, bacteria may be able to get in there and attach, but no water will flow by them to treat the water. The photo below was taken with a powerful electron microscope and it shows bacteria attached to the Filtralite material. For optimum treatment the water will flow directly through Filtralite material. (see picture on page 19)

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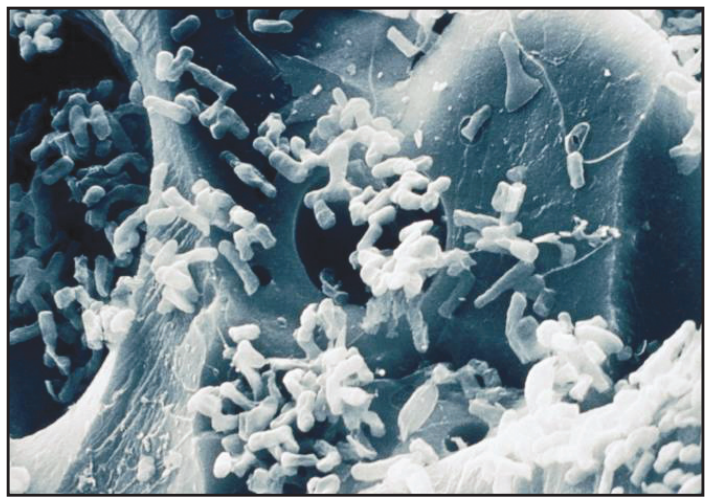

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Trillions of Biofilm Bacteria on Filtralite Material do the Heavy Lifting

Biofilm bacteria will, therefore, remove rotten egg smell and other smells from the water as well as compounds, such as iron, manganese, ammonium, organic material, arsenic and the list goes on. The bacteria will do all of these things if we can coach them to do so.

Water-purifying bacteria are only interested in compounds that can either be a nutrient source or energy source for them so even with the best coaching we will end up with compounds that have not been removed, such as sodium, sulphate, chloride, uranium, aluminum, refractive organic material etc. These compounds will flow to the RO process where they are removed.

It is essential that the RO membrane does not get damaged in the water treatment process. Using the IBROM biofiltration process ahead of the RO membranes assures that the RO membranes are protected from any damage. It is like treating something with kid gloves. Regular membrane cleaning can also damage the membranes, but we have developed a process where there is no damage. On top of that we still don't know how long we can run the IBROM process before the RO membranes need cleaning, which is great. The oldest continuously running IBROM plant, at Pasqua First Nation, has not required membrane cleaning since it was commissioned in 2005! To sum up, the entire goal with the biological treatment is to make the water suitable for treatment with a an RO membrane or, in rare cases, with a nano-filtration membrane.

Buyer beware

A nano-filtration membrane is sometimes used so that less adjustment of pH will be required as more ions are let through. Unfortunately, on most source waters, desirable ions, such as calcium and magnesium, will be removed while undesirable ions, such as ammonium, sodium, and chloride will go through. For all intents and purposes the ions that a nano-filtration system lets through are "garbage ions" that you don't want in your drinking water. As an RO membrane gets damaged it becomes more like a nano-membrane. If the engineering company has promised your community RO membranes, but you get nano-membranes instead, then you have been taken for a ride. But, how do you tell? The membrane vessels look the same. It is what is inside the membrane vessels that count. You need to check the treated water. Did the engineering company promise you calcium and magnesium? That's what is in treated IBROM water. If you have nano-membranes the ionic composition of your water may be more suitable for washing cars with than for drinking.

Poor quality water and RO membranes DO NOT mix

Poor quality water and RO membranes do not mix! Never have, never will. Some RO manufacturers have stated that a source water for an RO membrane needs to have less than 3 mg/L of dissolved organic carbon in it. Saddle Lake has 25 mg/L. RO manufacturers have tried to develop membranes that are fouling resistant, but with limited success. Few will need highly-fouling resistant membranes if you consider that many source waters can have low levels of organics with Calgary's water source running around 1.0 mg/L, 25 times lower than Saddle Lake.

Put an RO membrane directly on Saddle Lake water and it will likely plug in a couple of hours and it is not possible to squeeze any more water through the membrane. But, the Saddle Lake IBROM has now operated for 5 years without the RO membranes needing cleaning. Try putting Manganese Greensand process treatment ahead of an RO and you get a real mess. This by-now antiquated pre-treatment system is laughably inadequate to treat water ahead of an RO in some communities. This is what happened to the RO membranes at George Gordon First Nation.

Remember that the membranes are sparkling white when they are new or run without fouling in the IBROM process. We now have IBROM groundwater plants with tight RO membranes that have not required cleaning since commissioning more than 10 years ago. At George Gordon with Manganese Greensand pre-treatment ahead of his ROs Bob Pratt cleaned his membranes every week. This frequent cleaning does one more thing to the membranes – it damages the integrity of the membranes. Even one harsh membrane cleaning carried out according to the RO manufacturers' standard protocols can damage the structure of the RO membrane and many undesirable compounds can start to slip through.

How do you tell if your RO membranes are damaged?

If you notice that you need to add higher amounts of chlorine after a membrane cleaning you are dealing with damaged membranes. You need to measure TDS of the permeate water (this is what we drink) from the RO. Increases in TDS are again caused by damaged RO membranes. It may take a few cleanings before the damage will become measurable so keep watching your chlorine additions. If the permeate water smells bad then remember that those smells are typically caused by reduced gases such as hydrogen sulphide (rotten egg smell) but then at people's taps there is no smell. What happened? Bacteria in the treated water reservoir and distribution system had a feast. Bacteria in the distribution system is something that I expect Health Canada will deal with some 20 years from now. But, meanwhile, some such bacteria, like Mycobacteria grow on the sides of distribution system and household pipes and a main source of transmission for both these bacteria and trihalomethanes is from breathing in aerosols while showering.

The RO Dilemma: Scaling and Fouling

RO membrane after manganese greensand treatment at George Gordon First Nation, 2004, before the IBROM was installed. A membrane that is new or has *not* been fouled is white. SUBMITTED PHOTO

Many people around the world have now realized that if one were able to treat a poor quality water source with RO membranes the treated water quality will be high. However, what has eluded water treatment professionals is finding a sustainable way to treat the water *ahead* of the RO. Remember, an RO can have holes 30,000 times smaller than the width of a human hair. So if the water coming into an RO is not pristine the holes in the RO will plug.

Plugging can be caused by scaling when inorganic compounds like calcium and sulphate go from being dissolved in the water to forming solids. When you buy sugar it is a solid, but when you add it into your tea it becomes dissolved. With inorganic compounds the process that causes RO membranes to scale is exactly the opposite. These compounds are dissolved, but when they become solids they cause all kinds of problems in the membranes. Something called antiscalants are used to prevent the formation of inorganic solids (scale formation). But, like with everything else we have so much stuff in our water that antiscalants cannot keep everything in solution.

But then there is an even bigger problem for the RO to contend with: fouling. Fouling effectively plugs holes in membranes. There are a lot of things that can foul RO membranes. Fouling can be caused by organic material sticking to the membranes, it can be caused by food for bacteria in the water. Bacteria can then attach to the concentrate side of the membrane and all they need to do is to grow and reproduce: this will plug the membrane holes. Bacterial food is removed by the IBROM process, while other processes remove no or only small amounts of the food bacteria can use.

One reason for putting nano-membranes into a community (water treatment plant) rather than RO membranes was mentioned above as the decreased need to pH adjust the treated water even if this comes with a heavy cost as we get to drink garbage ions. However, lower requirements to pH adjust is often argued to be an advantage of using nano-filtration membranes when it really is not. A major reason why nano-membranes are installed is that they don't scale or foul as easy as RO membranes. So if a treatment company cannot produce a pristine water for the membranes to treat it is hoping that it will take longer for the nano-membranes to scale and foul.

The IBROM Treatment taking shape

Thinking about the magnitude of the water quality problems in Yellow Quill's raw water I started to realize that I, as a water treatment scientist, got the best gift ever – some of the chemically-poorest water sources on earth to play with. In other places they have a few problems in the raw water; in Saskatchewan we had, and continue to have, around a dozen problems both in ground water and in surface water. This is not about juggling two or three balls, this is about juggling a dozen.

The developed biological processes ahead of the RO resulted in no scaling or fouling of the RO membranes at Yellow Quill. Finally, the parts for an effective water treatment system were slowly coming together, optimized biological treatment followed by RO treatment. Now, we got pure water, H2O. The compounds that the bacteria did not remove will have been removed by the RO membrane. The RO membranes that I like push water through holes that are 30,000 times smaller than the width of a human hair. If you think about that, you realize that the biggest obstacle in treating poor quality water is the fact that poor quality water needs to be pushed through an RO to get to a quality that is safe to drink.

Two trail blazers at Indian Affairs

This is where the federal government fails First Nations. They fail to recognize how poor our raw water sources are, especially in Saskatchewan. They then apply water treatment technologies that are developed for treating water that is of much better quality than what First Nations have access to. Better technologies are needed for that poor quality water. The proposed technologies have never worked and will never work. But, two Indian Affairs officers, Jouko Kurkiniemi and Earl Kreutzer, truly turned the apple cart around helping us to finally find technical solutions for how to treat "untreatable water."

Jouko Kurkiniemi SUBMITTED PHOTO

These Indian Affairs staff moved water treatment forward in Saskatchewan as they realized that treating some of the poorest quality source waters in the world *simply cannot be done with conventional technologies.* There are a dozen problems in our water sources and we need to count to at least 12. What you can achieve with conventional treatment can be counted on one hand.

Earl Kreutzer SUBMITTED PHOTO

I am proud to say that before Jouko retired he asked me to check up on the quality of water treatment in First Nations communities. My reports back to Jouko included comments like: "The plant is like a dog's breakfast," Jouko responded to my description of this particular water plant: "I thought so." Now why did this Indian Affairs officer charged with looking after drinking water treatment in First Nations communities in Saskatchewan respond with: "I thought so?" I believe that in Jouko's mind at that time he was thinking that there were a lot of problems in drinking water treatment in Saskatchewan.

A dog's breakfast water treatment plant

Take the water treatment plant that I had called a "dog's breakfast." An engineering company at that time had spent $1 million designing the "dog's breakfast." Shortly thereafter I got a contract to run an IBROM pilot. It worked well. Yet to my utter disbelief the Band selected to retain the engineering company and spent another $1 million. Wow, an engineering company earning another million to fix up their own design blunder! When nobody can understand your black magic, you can get away with something like that. This community can thank its lucky stars that Jouko pushed an IBROM through after the community hired a different engineering company. Jouko felt bad that Indian Affairs had done such a poor job technically evaluating both the first and second INAC $1 million expenditures. Jouko warned the "dog's breakfast" engineering company to never ever try to pull such a fast one on him again. Earl Kreutzer was not happy about another water treatment plant and commented about it: "The engineering company should be ashamed of itself, Indian Affairs has a long memory."

We have other examples where engineering companies have tried to pull fast ones on Indian Affairs. The engineering companies proposing to use totally inappropriate technologies and then expecting that Indian Affairs not having the technical resources (this is for sure partly true) to properly evaluate their proposals. This, unfortunately, is happening too often, even in 2015. From an engineering perspective this is actually the most profitable scenario. First, get paid for designing something that will not work. Then get called back to spend months to try to get the water treatment plant to run. Finally, install an IBROM. The IBROM was field tested and piloted over 22 months on some of the poorest raw water sources anywhere. With another 15 IBROM plants in Alberta and Saskatchewan bringing truly safe drinking water that tastes great to the tables of First Nations families it is hard to understand why anybody would accept anything less?

Dr. Hans Peterson is the Safe Drinking Water Ambassador for the Safe Drinking Water Foundation (www.safewater.org). Dr. Hans is also a scientific advisor to the Safe Drinking Water Team (www.safedrinkingwaterteam.org). He will conclude his articles about the development of the IBROM process at Yellow Quill in the September issue of the Tribune.