Poor Quality Raw Waters Need More than Chemical Treatment

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In 2002 Aboriginal Affairs and Northern Development Canada (AANDC) and Associated Engineering (AE) were at a loss for how to deal with Yellow Quill's poor quality raw water.

Yellow Quill's raw water source (left) and Saskatoon's collected on the same day

AE had produced a report with half a dozen treatment technologies for Yellow Quill and AANDC to consider, but AE was not able to give the community any assurances that any of the suggested technologies would work.

Yellow Quill then managed to convince AANDC that the water treatment plant had to meet both current and future Guidelines for Canadian Drinking Water Quality. AE threw their hands up in the air and admitted that none of the suggested technologies would be able to meet even the current Guidelines for Canadian Drinking Water Quality.

For AANDC the options were not good. 1) Construct a 90 km long pipeline from a better quality source, but this would still require a water treatment plant. 2) Try to figure out how exceedingly poor quality ground water could be treated and made into drinking water. Yellow Quill ended up having a nine year boil water advisory, something that would be unimaginable in most communities.

Let me explain:
Any natural water source, whether from 10-1,000 m below ground, a river, or a lake, has one thing in common. They all contain compounds which bacteria can use to grow and prosper. Raw

water is to bacteria like one huge smorgasbord with smoked salmon, pickled herring, meat and potatoes.

This is the kind of water all water treatment plants around the world have to treat. The mix of food and the amounts vary, but even in a pristine mountain stream there are clear signs of a smorgasbord.

Conventional water treatment is based on using chemistry to remove or oxidize specific parts of the smorgasbord. Coagulation is used to bunch some things together so they are easier to remove and we use oxidation (potassium permanganate, chlorine etc.) to change the composition of the smorgasbord. This way we are able to remove iron, some manganese, and a few other compounds. But, in doing so, ideal conditions are generated for specific bacteria, such as manganese oxidizing bacteria that are given the exact conditions where they will thrive. The end result of this is bacterial regrowth in the distribution system or in a Reverse Osmosis (RO) membrane. This spells poor quality treated water for the community and membrane failure if RO membranes are used.

Let us take one specific example, the raw water that Yellow Quill First Nation is currently using. Yellow Quill's raw water contains 10 mg of iron/L. If we let the water sit open to air it will, over several hours, generate 0.5 million particles/mL. We will generate similar amounts of particles if we use other forms of aeration, oxygen additions or chemical oxidation.

Biologically treated water (left) and raw water that has been sitting in bottle for an hour or so (right). Raw water as it comes out of the ground also looks like the water in the left bottle for a few minutes.

Therefore, the potential is to generate 500 million particles per L. These particles are small and, in chemical treatment, the particles need to be trapped so that they will not get into the treated water. This is difficult and filter runs will typically be short.

Therefore, the first problem with chemical treatment is the generation of large quantities of particles and the generation of high filter head losses. The head loss of a filter is defined as the pressure at the top of the filter minus the pressure at the bottom of the filter. As this differential increases it is necessary to clean the filter, which is done by flowing water up through the filter which results in the removal of that which is plugging the filter. This is called backwashing.

Still, there is a further issue with chemical treatment, the generation of chemical conditions which do not exist in nature. Take, for example, the use of potassium permanganate and manganese greensand. The addition of potassium permanganate will generate chemical conditions that directly favour the growth of manganese oxidizing bacteria without having first fully removed either reduced iron or ammonium. This would never happen in the natural environment where biological removal of iron has to be completed before ammonium removal can proceed, and it is first then that biological manganese removal can occur.

Slime layers consisting of iron and manganese oxidizing bacteria

The conditions after manganese greensand treatment are, therefore, ideal for one specific group of bacteria, the manganese oxidizing bacteria. Manganese greensand treatment is designed to remove manganese, but typically trace levels of manganese remain in the water and will provide food for the manganese oxidizing bacteria. These conditions are generated in the filters, but the effects are manifested in the treated water reservoirs or in the distribution system. If an RO membrane is used then the removal will likely occur in slime layers composed of manganese oxidizing bacteria on the concentrate side of the membranes (brown membranes). The result is fouling that is very difficult to clean. Membrane cleanings may have to be implemented as often as daily (for example, at George Gordon First Nation before this water treatment plant switched to biological filtration).

If it is our intent to use an RO membrane to complete the treatment of a water, then it should be noted that the number one problem for sustainable membrane treatment is bacterial growth in the membranes. There are remedies for other membrane problems. For example,

precipitation of inorganic ions can be avoided using antiscalants, but there is no chemical remedy available to remove all bacterial nutrients and compounds bacteria can use for energy.

Chemical pre-treatment systems ahead of RO membranes are, therefore, bound to fail as they will generate particles that are trapped on the concentrate side of the membranes. In addition, chemical treatment will alter the composition of the water favouring the formation of bacterial biofilms on the RO membranes. While biofilm problems are initially generated by the altered water chemistry caused by chemical treatment, the formed biofilms will also trap particles leading to excessive cleanings and premature failure of the RO membranes. At George Gordon using chemical pre-treatment ahead of RO (manganese greensand) the RO membranes had to be cleaned daily and replaced every eight months.

A cut up RO membrane showing uniform layers of manganese oxidizing bacteria

This is a large number of hurdles. What can be done in order to sufficiently treat exceedingly poor quality source water in order to consistently provide drinking water which meets or exceeds Guidelines for Canadian Drinking Water Quality? Read Biological Water Treatment is the Solution, the next editorial that I am going to write, to find out.