The Power of Biology in Drinking Water Treatment

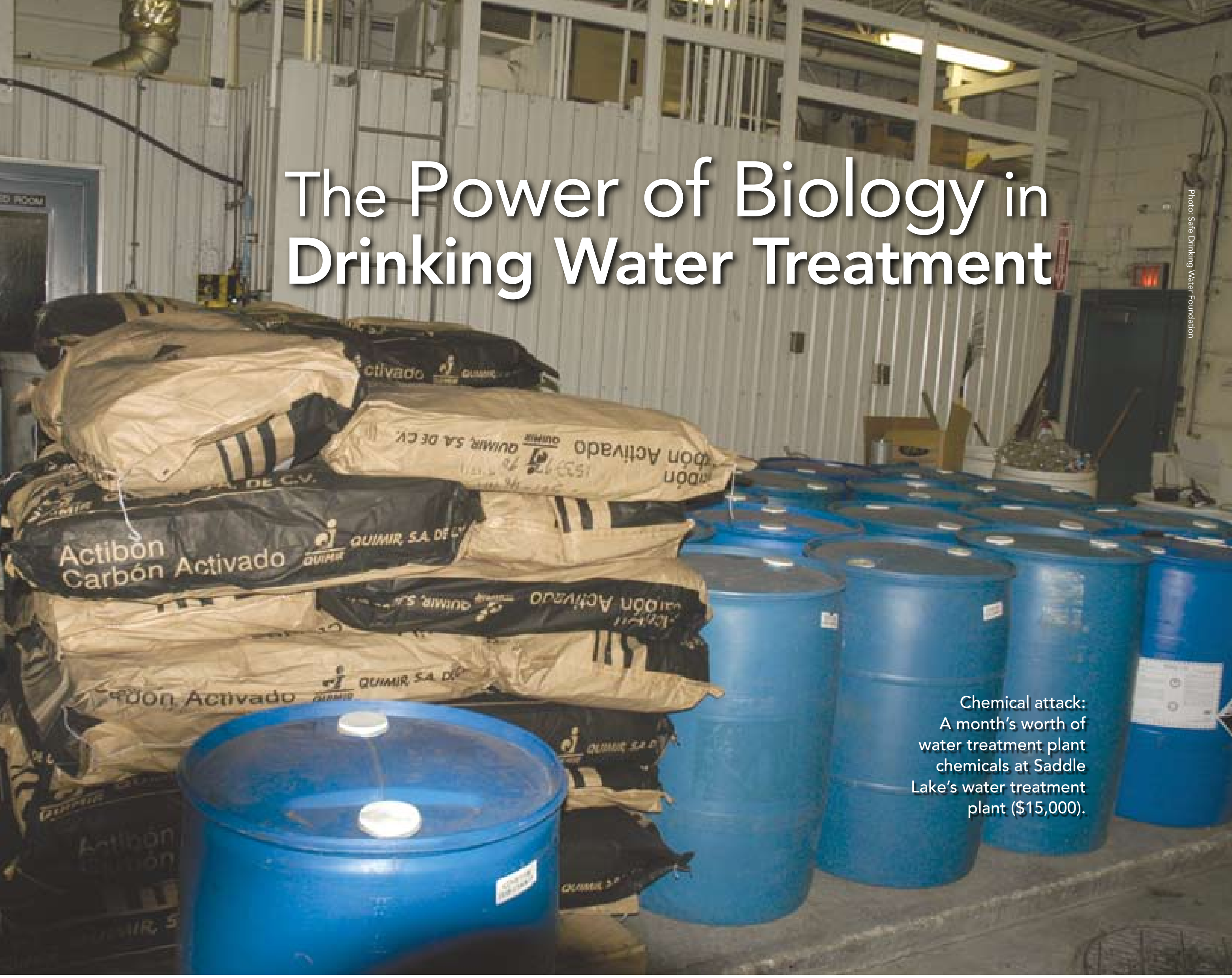


Photo: Safe Drinking Water Foundation

Chemical attack: A month's worth of water treatment plant chemicals at Saddle Lake's water treatment plant ($15,000).

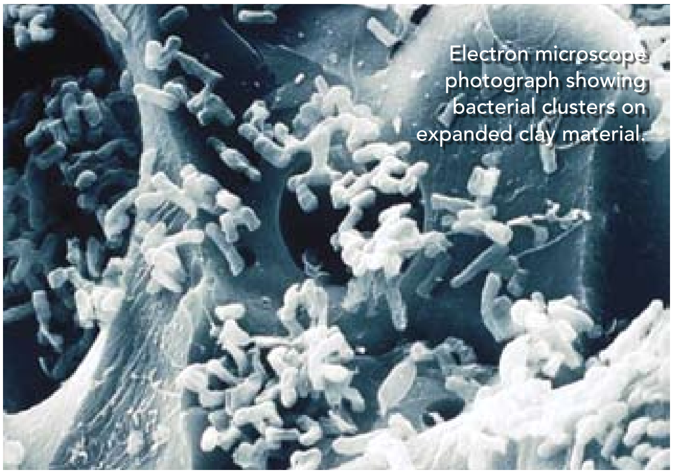
A biological treatment process for better water and improved working conditions.

By Dr. Hans Peterson

The first filters for municipal drinking water treatment were slow sand filters –where water is passed through a bed of fine sand at slow speeds – developed almost 200 years ago in England. The sand bed is typically around one metre in depth and flow rates range from 0.1 to 0.3 metres per hour (m/h). Particles are generally trapped in the top 0.5 to 2 cm depth of the filter with filter scrapings being the general method of cleaning the filters. However, until there is a layer formed on top of the sand containing bacteria, protozoa, algae, zooplankton and other organisms, treatment efficiency is low. The development of this "schmutzdecke" (German for dirty layer) is essential for treatment effectiveness of the slow sand filters. This is the first use of biology to treat drinking water. There are slow sand filtration plants, constructed almost 100 years ago, which are still in use still today.

There are limitations of slow sand filters, in that the water must be low in algae and particles for them to work. In North America the interest in slow sand filtration decreased in the 1920s with water treatment plants moving towards rapid sand filtration. Rapid sand filtration has flows in the 4 to 25 m/h (2-10 U.S. gpm/square foot) range allowing the use of much smaller filters. Instead of trapping particles at the very top of the filters, rapid sand filtration allows deeper penetration into the sand bed. To clean rapid sand filters there is a need to flow water from the opposite direction (backwashing). Biological processing in rapid sand filters is minimal and producing a high quality drinking water is based on the use of chemistry.

Even the notion that biological processes were occurring in water treatment plants made engineers nervous, and a "disinfection culture" was established in North American water treatment plants. This manifested itself in disinfecting water using various oxidants – such as potassium permanganate and chlorine – as soon as the water entered the plant. This ensured that whatever treatment happened in the plant it was not biological. Chemical engineers have been in high demand, concocting brews to remove inert particles, micro-organisms,



Electron microscope photograph showing bacterial clusters on expanded clay material.

Photo: Safe Drinking Water Foundation

Improved treatment at less cost will hopefully be part of implementing sustainable drinking water treatment solutions in Canada's marginalized aboriginal and rural communities.

dissolved inorganic, and dissolved organic material. Different types of oxidants, coagulation chemicals, acids, bases, and activated carbon entered the water treatment market in increasing quantities and combinations during the past 100 years.

Following the onslaught of chemistry, the rapid sand filters were supposed to remove chemical residuals from the treatment processes. It has, however, been realized that not only are treatment chemicals not always removed by the rapid filters, but the treatment chemicals themselves are generating new chemicals that can make the water unsuitable to drink. The discovery of chlorine reacting with organic material and forming disinfection by-products in 1974 led the United States Environmental Protection Agency in 1979 to impose limits on some of these compounds. Only one of these groups of compounds, the trihalomethanes, has guidelines in Canada, while other groups, the haloacetic acids, are regulated elsewhere. There are many more chlorination by-products that we know very little about and restricting the amount organic material at the time of chlorination will be a key future requirement.

The practice of trying to maintain a disinfected water supply through oxidation before filtration (pre-oxidation) has led to damage of organisms in the water, algae and bacteria, causing their contents to leach into the water. If blue-green algae are in the water, as is frequently the case for surface water supplies, both toxins and taste and odour compounds may be released. One problem with this is that most water treatment plants do not test for these compounds, although Health Canada now has a guideline for one blue-green algal toxin – microcystin. But, the generation of increased levels of disinfection by-products has been the main reason for a reduction in the use of "pre-oxidation" chemicals.

Another challenge with the chemistry approach have been the release of high levels of treatment chemicals, such as aluminum from the coagulation process. Aluminum is a chemical thought to be involved in human illnesses including Alzheimer's disease. This has led plants to try various combinations of aluminum formulations, polymers, changing to iron-based chemicals etc. The chemical battle rages on with further challenges including very large environmental footprints, disposal of used chemicals etc.

In Europe there has been less emphasis on having water disinfected as it enters the treatment plant and the thought of improving on the biological capabilities of the "schmutzdecke" first led to the use of porous materials instead of sand in order to increase the surface area where bacteria can attach to and purify the water. The power of biology was starting to be realized and a search for the perfect "home" for bacteria had escalated into a race with high stakes. Porous filtration materials, granular activated carbons and expanded clays have been developed where very high densities of naturally occurring bacteria attach treating the water as rapidly as in rapid sand filters.

Water is becoming a precious commodity, and at the same time the problems associated with waging chemical warfare in its treatment is causing environmental problems. The notion that biological processes can do similar things with no chemicals and all the accompanying associated advantages is starting to sink in.

Compounds present in water can be removed by bacteria providing they are either a nutrient or an energy source for the

Photo: Safe Drinking Water Foundation

A cut open RO membrane fouled by manganese oxidizing bacteria leaving a brown jelly-like coating on top of a bright membrane sheet (George Gordon First Nation water treatment plant).

bacteria. Many compounds can be both a nutrient and an energy source, such as iron. The compounds that can be either a nutrient or an energy source include ammonium, arsenic, dissolved organic carbon, iron, manganese and phosphate.

In water treatment, focus is squarely on compounds that can cause human health or aesthetic issues and treatment processes are designed to deal with this. However, compounds not in any guidelines, including bacterial nutrients and energy sources, can play havoc with advanced water treatment processes, such as reverse osmosis (RO) membrane filtration, and can generate thick slime layers in the distribution system. Virtually all oxidation processes will increase both bacterial nutrients and energy compounds. One example of how energy and nutrients from bacteria can cause in-plant water treatment problems and how biological treatment can resolve these issues is given below.

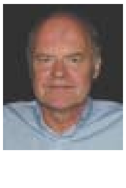
At the George Gordon First Nation, manganese greensand, followed by chlorination and distribution, was used from 1989 to 2001. It was, however, shown through daily testing by the water treatment plant operator that manganese levels were almost always above guidelines, iron levels were sporadically high, and the process could not assure the removal of high arsenic levels (greater than 70 micrograms per litre). Therefore in 2001, RO membranes were installed. However, both chemical and microbial fouling of the RO membranes became apparent, and despite frequent cleanings, the membranes became permanently fouled after just one year and a second set was fouled within eight months. Microbial and chemical analysis of the fouled membranes showed that extensive biofouling was accompanied by several different compounds covering the white membrane with a brown layer of fouling material. Microorganisms, including manganese-oxidizing bacteria, were present in the biofilms that covered the membrane. The bacteria formed jelly-like substances preventing the movement of water from one side to the next.

A biological process to remove nutrient and energy sources from poor quality groundwater sources, similar to those at the George Gordon First Nation, had been developed in 2002/2003 at Yellow Quill First Nation. This process is composed of biological treatment followed by RO treatment. Since the Yellow Quill plant was commissioned in 2003 the RO membranes have only been cleaned once and membrane life expectancy is more than 10 years. Encouraged by this data, the manganese green sand was removed from the filters at Gordon's and replaced by Filtralite expanded clay attachment material. This resulted in rapid improvement of treated water quality and an immediate end to frequent RO cleanings.

A comparison of the biological treatment with the manganese greensand treatment is starting to show the true power of biology as opposed to chemistry when drinking water is treated. Not only is it possible to produce much better quality water, but the work conditions for the water operators are much improved. At the Gordon First Nation water treatment plant the biological filters need to be backwashed 36 times less often than the manganese greensand filters. Backwash water use has decreased to 0.4 million litres from 23 million litres and backwash labor decreased to 40 hours from 1,440 hours per year. Combining these savings with decreased RO cleanings, no need for frequent membrane replacements, and decreased chemical costs, it has been estimated that this water treatment plant serving 1,200 people will save more than $100,000 per year. Improved treatment at less cost will hopefully be part of implementing sustainable drinking water treatment solutions in Canada's marginalized aboriginal communities and rural communities.

A two year development project at Saddle Lake Cree Nation has shown that $15,000 per month in chemical costs to treat its water can be cut to less than $1,000 when biological treatment followed by RO replaces its current chemical treatment and ultrafiltration membrane system; an additional benefit of the developed treatment is that Saddle Lake's three-year-old boil water advisory can then also be lifted.

It is time to start seriously teaching biology at Canada's engineering schools. W



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