Ensuring the Safety of Small Rural Water Systems

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Water Problems for Rural Canadians and the Agri-Food Sector

In Canada, over 4 million Canadians (13% of the population) rely on private water supplies, mostly from ground water sources. These Canadians are responsible for the supply, delivery, treatment and testing of their own drinking water and household water. During the period 1974-1996, private water supplies accounted for about 20% of Canada's reported infectious waterborne disease outbreaks, while non-municipal water systems largely in rural or remote areas accounted for an additional 45% of reported outbreaks. Thirty-five percent (35%) of the reported waterborne disease outbreaks occurred in municipal systems. (Robertson and Neil, 2001).

Studies in Alberta, Saskatchewan and Ontario have found that roughly 30 to 35% of wells exceed safe levels for bacteria (Fitzgerald *et al*, 1997, Sketchell and Shaheen, 2001, Rudolph and Goss, 1993). Unsafe levels of other health-related parameters also commonly occur (nitrates, arsenic, selenium, *etc.*).

Water quality may also exceed Canadian guidelines for non-health related issues. These problems are essentially due to the natural characteristics of the water in the aquifer.

Examples include hardness (calcium, magnesium), iron, manganese, sulphate, sodium, dissolved organic carbon, colour, *etc.* Studies have shown that 92 % of private wells in Alberta and 99% in Saskatchewan exceed Canadian guidelines for health and non-health related parameters.

Water quality problems affect both the rural population and the agricultural sector. Water use is impaired for household drinking water, washing and cooking. Unsafe bacterial or chemical levels would affect human health if treatment was not used. Non-health issues such as iron, manganese, calcium and magnesium will affect household cleaning operations (washing clothes, dishes, general cleaning), and often will stain, encrust or damage household plumbing, fixtures and appliances.

Poor quality water also affects agricultural production. Diversification options such as food or non-food processing (*e.g.* dairy operations) are simply not possible nor practical without extensive water treatment to ensure the safety of the water for the processing and cleaning operations. Livestock health and animal weight gain may be impaired. Water quality can interfere with animal feed mixes. In severe cases, animal deaths occur, such as cyanobacterial toxin poisonings from surface water supplies. Water used to mix chemicals for crop spraying may antagonize the active chemical ingredient and reduce or negate its effectiveness. Watering bowls, nozzles, animal misters, boilers, pipes, water distribution systems and other equipment may foul, clog, plug up or simply stop performing.

Unfortunately, 53% of Canadian farms do not test their water regularly. The highest percentage, 67%, occurs in Alberta (FEMS, 2001). To compound matters, point-of-use and point-of-entry water treatment devices are not regulated in Canada. Many vendors simply do not design systems to deal with the spectrum of problems that any one water supply may have. In a Saskatchewan survey, Prairie Research Associates Inc. concluded that 63% of survey respondents believed that "many people have been sold water treatment systems that don't work"(Mason, 2000).

The survey also noted that certain federal and provincial agencies have a high credibility among producers and processors. The rural respondents desire more unbiased water quality information from federal and provincial agencies, in the form of fact sheets, informational articles, news media, the Internet, and in-person extension activities.

Canada-Saskatchewan Agri-Food Innovation Fund's Rural Water Quality Program(RWQP)

Recognizing the critical nature of water quality for the rural population and the agri-food sector, the Rural Water Quality Program (RWQP) was established under the Canada-Saskatchewan Agri-Food Innovation Fund. The RWQP conducted applied research in three categories:

- Protection of water supplies (Best Management Practices for farm operations)
- Enhancement of water sources (well maintenance and surface water management)
- Treatment (innovative small-scale processes suited to farm needs)

In all cases, scientific studies were linked to technology transfer activities. This ensured that new information and knowledge was extended to agricultural producers, agricultural industry, and the general public. Many resources were posted to the Internet at: www.agr.gc.ca/pfra, following the links to Clean Water.

A literature review was conducted on "Water Quality Requirements for Saskatchewan's Agri-Food Industry" (Peterson, 2000, http://www.agr.gc.ca/pfra/water/facts/wqreq.pdf). Water quality guidelines were summarized for each agri-food sector: livestock watering, irrigation, micro-irrigation for horticulture, water use for mixing farm chemicals, agricultural industrial processing, and on-farm domestic uses. This is a valuable reference document for producers, agricultural industry, the agri-food services sector (*e.g.* engineers) and government extension personnel.

Protection of Water Supplies with Agricultural Best Management Practices

Virtually all aspects of agricultural production rely on interactions with the environment, from livestock and crop production, to value-added processing and diversification activities. The agricultural sector adopts Best Management Practices(BMPs) for optimum production and environmental protection.

BMP adoption requires an understanding of the effectiveness of a particular practice. For example, a remote watering device pumping water from a water source to a trough must be capable of working during summer and winter.

A literature review was conducted to determine best practices suited to the Canadian prairie (*e.g.* conservation tillage and grassed waterways to control erosion, remote watering of livestock to reduce impact on water bodies, nutrient management to control contamination from animal waste, *etc.*)
(Hilliard *et al*, 2002, http://www.agr.gc.ca/pfra/water/wqbmp_e.pdf).

An economic study proved that protection practices can increase profits in some cases. For example better livestock water may result in more effective animal weight gain or better pesticide performance, and reduced water treatment or infrastructure costs (Russell, 2000).

A sociological study found that farmers care for the environment and regularly adopt BMPs. However, it was apparent that BMP adoption was more commonly occurring when production was profitable. BMP adoption is less likely to occur when farmers are confronting an income crisis. (Kehrig, 2002). The study also found that farmers believe more scientific studies are needed to evaluate the performance of BMPs, determine economic costs, and demonstrate technologies. For a BMP to be adopted, it must work, and be economical and practical.

Remote livestock watering systems were tested and operated in field conditions, summer and winter. The technologies were demonstrated at research farms and private locations. Tours and media coverage were used to transfer the knowledge of practical applications for the livestock industry. Adoption of remote watering systems is rapidly increasing, and will result in protection of adjacent water bodies.

Farm chemical spraying is used to control pests. Timing and application methods are critical factors in ensuring the chemical reaches the target pest (*e.g.* weeds). Atmospheric drift may be a problem. Investigations into the performance of different nozzle designs proved that some nozzles are very effective in minimizing drift. Low-drift spray nozzles reduced airborne transport by 75%. Other investigations determined that riparian buffers adjacent to water bodies reduced chemical drift by as much as 97% when low-drift nozzles were used, or 82% when conventional nozzles were used (Wolf and Cessna, 2002.)

Tillage of farm land affects the transport of agricultural inputs (fertilizers and chemicals). Studies were conducted comparing different tillage practices. Zero-tillage reduced water runoff from the land and increased water infiltration into the soil. Agricultural modeling was also compared, and the Cold Region Hydrology Model showed promise in measuring snowmelt runoff (Elliott and Cessna, 2001). This information is useful in developing BMPs for cropping practices, to protect contamination from agricultural inputs.

Irrigation is a concern because larger inputs are required to grow higher-value crops. Agro-chemical leaching was studied on potato irrigation. BMPs were investigated for application of fertilizers, herbicides and irrigation water (Elliot *et al*, 2001).

Enhancement of Wells and Farm Dugouts(Ponds)

Many private wells are susceptible to reduced performance and water quality deterioration due to biological fouling. Bacteria (*e.g.* iron, sulphate-reducing, slime-forming bacteria, *etc.*) are natural organisms present in many aquifers. Their prevalence poses unique well maintenance challenges, since the bacteria may resist common preventive maintenance procedures such as shock chlorination. Investigations were conducted to determine the suitability of Ultra-Acid Base™ (UAB ™) well treatments. The process may not be effective on severely biofouled wells (Agriculture and Agri-Food Canada, 1997, 1998, http://www.agr.gc.ca/pfra/water/swwi_e.htm). Evaluation of source water for potential biofouling problems was also investigated using BART™ methods (Biological Activity Reaction Tests). These commercially-available tests were found to be helpful in determining potential well maintenance methods.

Many farms across Canada and the world utilize farm ponds constructed in clay soils to store water for general use, and occasionally domestic use. Farm dugouts are commonly

20 m by 70 m by 3.5 m deep or larger. Most dugouts store about 2 to 7 million liters. They fill primarily by snowmelt runoff from the land, with some rain inputs. In winter, for about 6 months they are covered by about 1m of ice. Farm dugouts are prone to significant problems with organic-rich material, including dissolved organic carbon, nutrients, algae, *etc.*. BMPs for dugouts attempt to prevent nutrient inputs, but internal recycling from organic soil and sediment occurs naturally. Investigations into the use of diffused aeration systems working 24 hours/day 365 days/year were proven to be very effective at reducing internal nutrient recycling, with improved water quality year round. Dugout aeration is a recommended BMP for all farm ponds. Many methods (*e.g.* solar or wind systems) can be utilized, even for aerating remote sites. A series of publications were produced to assist producers with aeration techniques (http://www.agr.gc.ca/pfra/water/quality_e.htm).

Small-scale Rural Water Treatment

Access to effective and economical small-scale water treatment processes is an issue for rural Canadians and the agri-food sector. Most technologies that are considered essential for municipal water treatment are not available at a scale and cost suited for rural uses. When technologies are available, problems often occur with operation and maintenance. Rural people can expect to pay up to seven times more for equal volumes of quality water in comparison to people served on municipal systems (Russell, 2001).

Investigations were conducted to determine whether or not proven or innovative processes could be scaled down for use on farms.

Coagulation was adapted for applications to farm dugouts, suitable for remediation of a dugout. Over 130 dugouts were treated after the 1997 Manitoba Red River Flood. A coagulation cell constructed in clay soils, lined with plastic material, was designed for year-round storage of household water and treatment twice yearly. Coagulation chemicals were mixed into the water with an electric boat motor. Significant reductions (>60%) in turbidity, colour, dissolved organic carbon, phosphorus, *etc*. were achieved. A Saskatchewan firm designed a batch treatment system, which is now patented and commercialized for use on farms and in small communities (Schuba, 2001). Simple predictive tests to determine the correct coagulation chemical dose were developed to ensure safe effective coagulation treatments could be achieved by producers. Information on coagulation benefits and procedures is available in a variety of formats suited to rural people and the agricultural sector (http://www.agr.gc.ca/pfra/water/quality_e.htm).

Biological Filtration was field-tested at a number of farms. Slow sand filtration removed iron and arsenic, and intermittently removed manganese from ground water sources. Biological granular activated carbon systems using long contact times, with air injection and continuous filter re-circulation were proven to effectively remove dissolved organic carbon from surface water sources (Peterson, 2000). Systems have performed for periods of over 7 years, whereas conventional small-scale rapid granular activated carbon filters lasted several months.

A biological process known as sulfur/limestone autotrophic de-nitrification (SLAD), used for removal of nitrate-contaminated water sources, was field-tested and compared to ion exchange and membrane processes. The SLAD method was found to be suitable for rural use and considered to be significantly more economical (Viraraghavan and Darbi, 2003).

Membrane Filtration was evaluated for a variety of applications (household, livestock watering, dairy, centralized treatment for a rural pipeline). Rural application of membranes requires a good understanding of the source water to be treated and the limitations of the membrane, to determine pre-treatment requirements. Advances in membrane technology make the technology promising for small-scale systems. However, successful applications require long-term pilot studies to determine optimum design, performance, membrane replacement and cleaning, and disposal options for the rejected water from the membrane process (Gagnon and Tremblay, 2001). The Cutbank Rural Pipeline Utility operated a pilot nanofilter for several years before deciding to add on a micro-filter, as an integrated membrane system. The improved pre-treatment was necessary to prevent poor nanofilter performance caused by diatom algae during the summer months (Morrison and Ullyott, 2001).

On-Farm Water Treatment Design and Disinfection

Farm water treatment processes are often incorrectly positioned in a treatment train. For example, chlorination systems are often installed before a carbon filter, without any post-disinfection. This compromises the microbial safety of the distributed water.

Treatment trains were evaluated and compared on surface water. One treatment train included coagulation, sand filtration and carbon filtration followed by disinfection. A second treatment train included slow sand filtration, biological granular activated carbon filtration, storage and post disinfection. Post-disinfection utilized either a chlorinator or ultra-violet lamp, followed by a polishing reverse osmosis unit. Performance data was gathered for these small-scale multiple-barrier water treatment systems. Information was shared among federal and provincial sponsors of Prairie Water News, an inter-agency newsletter (http://www.quantumlynx.com/water/). Treatment recommendations were published in Quality Farm Dugouts targeting rural people.
(Alberta Agriculture, Food and Rural Development, 2002,
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng4696).

Linking Science to Technology Transfer

Getting information, knowledge and technology to clients, the agri-food sector and the public requires a concerted effort, targeted funds and a communications strategy. A technology transfer plan was developed and research teams worked with a communications officer on tech transfer activities suited to each project (Street, 2000). Linking applied science to technology transfer has been judged a success by external evaluators (Fairley *et al*, 2001). The research leaders were recognized as "Leaders in Sustainable Development" by a jury of public and scientists representing Canada's 5NR, the natural resources departments of Health Canada, Environment Canada, Natural Resources Canada, Fisheries and Oceans, and Agriculture and Agri-Food Canada. A key reason for this recognition related to the efforts to bring knowledge and science to a widespread public audience. The technology transfer activities included developing fact sheets, demonstrating technologies at trade shows, work shops and field days, promoting media coverage, publishing papers in journals and conferences, and other unique activities, such as:

- **Field of Streams at the Saskatchewan Science Centre** - this permanent display allows children and adults the opportunity to manipulate an agricultural landscape to understand how BMPs can be utilized to protect water sources.
- **Robocow** - this entertaining Flash animation depicts a superhero cow scanning farms for risky practices that can be improved with BMP adoption. Robocow was presented with an "Award of Merit for Excellence in Dealing with a Controversial Subject" by the Association for Media and Technology in Education in Canada. (Internet posted at http://www.agr.gc.ca/pfra/flash/robocow/en/robocow_e.htm)
- **Water is Life** - technical and financial support was provided for this Ag Study Series booklet published by Agriculture in the Classroom. A resource for teachers and students, it was distributed to every school in Saskatchewan and to organizations in seven Canadian provinces.
  (Internet posted at: http://www.saskschools.ca/~aitc/booklets/water.pdf ; http://www.aitc.sk.ca/agstudyseries/water.pdf)
- **Farm Surface Water Management** is a series of Flash animations depicting technologies in simple graphics, to help rural people and others better understand

what can be done to protect, enhance and treat water at the farm scale (Internet posted at: http://www.agr.gc.ca/pfra/flash/onfarm/en/onfarm_e.htm).

Summary

Water quality protection and treatment is a concern for rural Canadians and the agri-food sector. Agriculture and Agri-Food Canada is embarking on a new "Agricultural Policy Framework". Priorities include security of the food system, health of the environment and scientific innovation for growth. The projects completed under the Rural Water Quality Program dealt with each of these priorities as they relate to rural water quality and sustainable development. The Rural Water Quality Program has ended. The current challenge is to find new ways to continue collaborative efforts dealing with rural water quality issues. Interdisciplinary research is essential. Linking science to technology transfer is a proven and successful model, benefitting the agri-food sector and the Canadian public.

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