Quality Assurance. Quality assurance testing of laboratory performance suggests that there are many more organisms in the creeks, sewage effluent and the river than were measured. Laboratory performance was tested twice during the study. Samples with known numbers of parasites as well as samples with none (called "blanks") were sent to EPCOR (and three other labs). The test is evaluated by comparing the number that the laboratory found in the prepared test sample with the known number in that test sample. The percentage is called "recovery."

Counts for giardia in the test samples were much lower than the actual number and therefore all four laboratories failed the test. For cryptosporidium, EPCOR passed in the 2000 test, but failed in 1999. Overall recovery was 28 % for cryptosporidium and 14 % for giardia. The analytical method, which was developed by the United States Environmental Protection Agency (USEPA), is continuing to be improved, but still relies on the ability of the person analyzing the sample to find and identify these organisms under a microscope. If there are many other objects of a similar size and shape on the slide, the task is very difficult.

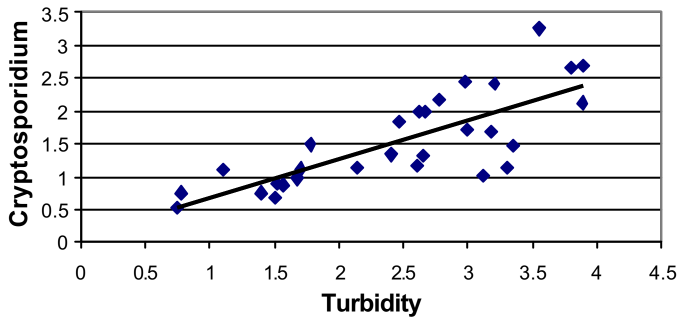
EPCOR routinely tests performance in its laboratory using test material with known numbers of organisms. During 1998 – 2000, average recovery ranged between 18% and 31% for cryptosporidium and between 31% and 43% for giardia. This is considerably better than the results for the tests done for the study, and similar to recoveries in labs in the United States using the same analytical method. This suggests that there may have been problems with the test material used in the two performance tests during the study, especially as the giardia cysts used in the test appeared shriveled and difficult to recognize.

Although it may seem that the performance tests bring into question the results of the study, the relationships established were based on similar errors throughout the study. For example, correlations between watershed characteristics and cryptosporidium would be the same whether 28 % or 100 % of the organisms were consistently counted. Unfortunately, the USEPA analytical method used during the study was the best available at the time. Eventually, however, the errors associated with sampling and analysis of these organisms will be reduced as new methods are developed.

Relationship Between Land Use and Water Quality

Livestock in the North Saskatchewan River watershed appears to increase levels of parasites in streams. A "relationship" between a certain land-use factor, such as number of cattle, and water quality in a stream means that as the land use changes, the water quality does as well. Although a statistical relationship is not 'proof' that a particular land use activity influences levels of contaminants in a stream, it provides an excellent indication that it does. This is especially true if the relationship or correlation is strong (see box on next page).

Correlation. A correlation is a statistical relationship between pairs of values. For example, both turbidity and cryptosporidium are measured in a water sample. If a number of samples are collected and analyzed, we can statistically test whether there is a relationship between them – in other words, do the numbers of oocysts increase when turbidity increases? The closeness of the paired values to a straight line indicates the strength of the relationship. For cryptosporidium and turbidity, the relationship is quite strong.



For this part of the study, concentrations of parasites and other water quality characteristics were statistically compared with a variety of land use factors: density of cattle and other livestock, percentage of cattle yards along streams, runoff potential, vegetation, rural population, wastewater discharges, beaver activity and percent of stream length grazed by livestock. The water quality data from the Longitudinal, Intensive Watershed and Synoptic surveys were compared with these land use factors.

Canada Census of Agriculture information was used as a basis for determining relative differences in land use throughout the basin. More specific information was obtained by interviewing landowners in the Mishow, Tomahawk, Weed and Strawberry Creek watersheds. Land use along these streams was also surveyed by driving around the watershed. Beaver activity in the six intensive watershed streams was surveyed by aircraft.

For statistical analyses, Mishow, Tomahawk, Weed and Strawberry creek watersheds were lumped into one category that represented the influence of livestock production, because there was statistically little difference among them ("agricultural watersheds"). Baptiste and Nordegg watersheds, which are primarily forested, represented influences only from wildlife ("non-agricultural watersheds").

In the Longitudinal Survey streams, all water quality concentrations, including both parasites, were correlated with the runoff potential index in spring and summer. Runoff moves parasites from their source on the land into a creek, and one would expect higher concentrations in the creek draining land with a high runoff potential.

Total livestock density was correlated with concentrations of cryptosporidium and giardia during the spring and summer. There was no correlation with municipal wastewater discharges.

For the Intensive Watershed streams, concentrations of parasites in the four agricultural streams were significantly higher than concentrations in the two non-agricultural streams. In spring, cryptosporidium levels were not correlated with beef cattle density while giardia levels were strongly correlated. Stream parasite concentrations were correlated with the percent area of cattle yards along streams, total livestock density and human population density. Watershed human population density was strongly correlated with cattle densities and streamside cattle yards, which is not surprising as cattle yards and farm residences usually occupy the same location.

In summer, cryptosporidium was correlated with dairy cattle, hogs and total livestock densities, while giardia was correlated with several livestock types and watershed grazing factors. Nutrient concentrations (phosphorus and nitrogen) were also strongly correlated with the density of a variety of livestock in spring and summer. Hog, sheep and goat, horse and other livestock densities also showed some relationship to parasite levels in the streams.

There was no correlation between levels of cryptosporidium or giardia and beaver activity (dams, houses and feed piles) along the six Intensive Watershed streams. However, water sampling on a tributary of Strawberry Creek before and after two beaver dams were blown showed a dramatic increase in parasite levels in the stream. This confirms that these parasites do accumulate behind beaver dams from all sources upstream, not only beavers.

Summary and Conclusions

The North Saskatchewan River basin is large, with a multitude of land-use activities and sources of parasites. These parasites are transported from specific sources on the land to the river by runoff, which gathers in streams and finally enters the river. Because it is virtually impossible to pinpoint the movement of organisms from these non-point sources to the river over such a large land area, this study was designed to look at relationships between land-use factors, such as cattle density, and concentrations of parasites in streams that drain to the river.

As well, numbers of parasites entering the river in streams draining agricultural watersheds (those with livestock) were compared with those draining non-agricultural or forested watersheds (those influenced primarily by wildlife). Municipal sewage effluent is also a potential source and therefore loads from municipal sewage treatment facilities were compared with those from streams.

Two questions were addressed during the study:

- *Do cattle in cow-calf operations contribute significant amounts of cryptosporidium and giardia to surface water compared with wildlife and municipal sewage effluent?*

- *Do watersheds with high densities of cattle and other livestock contribute greater quantities of cryptosporidium and giardia to the North Saskatchewan River than non-agricultural (forested) watersheds?*

Key findings that address these questions are as follows:

Parasite Prevalence

- Concentration and prevalence of giardia in beef cattle feces were higher than in feces from any other type of livestock or wildlife, except for muskrat. Concentration of cryptosporidium was moderately high in beef cattle feces, although prevalence was low. Concentration and prevalence of cryptosporidium were also moderately high in dairy cattle, although not as high as in ranched elk.

- Prevalence and concentration of cryptosporidium in wildlife fecal samples were zero or low, although prevalence and concentration may have been affected by freshness of the sample. Prevalence and concentration of giardia were high in muskrat samples, whereas those from beaver and coyote were moderate.

Water Quality

- Streams draining agricultural lands contributed the highest loads of parasites to the North Saskatchewan River, compared with loads from sewage effluent, non-agricultural streams and from the watershed above Rocky Mountain House. However, streams draining non-agricultural (forested) areas occasionally contribute relatively high loads during summer storm events. On average, agricultural watersheds contributed 56% of the cryptosporidium load and 79% of the giardia load in the river at Edmonton in spring and summer.

- Giardia concentrations were high in municipal sewage effluent; however, the total giardia load from municipal sewage facilities was small (less than 2% of the total load entering the North Saskatchewan River during runoff periods) when compared with the total parasite load from the watersheds. Cryptosporidium loads were even smaller. Municipal sewage effluents from the facilities that discharge continuously contribute a year-round base load of giardia to the river. These effluents tend to be a primary source during the winter and likely at other times of the year when river flows are low.

Relationship Between Land Use and Water Quality

- Concentrations of cryptosporidium and giardia were significantly higher in streams draining watersheds with more intensive agricultural (livestock) production, compared with non-agricultural watersheds.

- In spring, levels of cryptosporidium and giardia in streams were correlated with total livestock density and percentage of cattle yards along watershed streams. As well, giardia levels were correlated with density of beef cattle in spring. In summer, levels of both organisms were correlated with total livestock density. Giardia was also correlated with beef cattle density and grazing factors, whereas cryptosporidium was also correlated with density of dairy cattle and hogs. In fall, giardia concentrations were correlated with dairy cattle and hogs.

- There was no correlation between municipal wastewater discharges and stream parasite levels.

Cryptosporidium and giardia are common in the North Saskatchewan River basin. These parasites were found in feces from livestock and wildlife as well as in raw municipal sewage. Parasites were also present in streams draining non-agricultural and agricultural watersheds, in treated municipal sewage effluents and in the raw source for drinking water. As well, they were present in the North Saskatchewan River at Rocky Mountain House, which represents the watershed above the study area. In treated drinking water, they were undetectable or at such low levels that there would be no cause for concern, although there is some risk from peak parasite levels during major runoff events.

The primary source of parasites, bacteria, nutrients, organic matter and other water quality variables in the North Saskatchewan River is the nonpoint source runoff from the agricultural watersheds as opposed to point sources like wastewater effluents. In general, areas of the North Saskatchewan River basin with high runoff potential contributed more parasites than areas where the runoff potential was low. This emphasizes the importance of runoff processes in surface water contamination.

It is likely that beaver and muskrat contribute to stream giardia levels, as concentrations in feces from both species were relatively high. However, there was no correlation between beaver activity along the streams and stream parasite levels. Beaver dams may retain parasites from the watershed above them. The prevalence of cryptosporidium in wildlife feces was so low that they are an unlikely source of this organism.

The results of the sampling program upstream and downstream of individual cattle operations are inconclusive, although concentrations of giardia were significantly higher downstream of one cattle operation, compared with upstream.

Based on the relatively high prevalence and concentration of cryptosporidium and giardia in livestock feces; the higher concentrations and loads of parasites in agricultural streams compared with non-agricultural streams; and the correlations between numbers of parasites in streams and livestock land-use factors, it appears that livestock (including beef and dairy cattle, ranched elk and bison) are a major source of parasites to the river. However, further research into polymerase chair reaction (PCR) and other DNA-identifying technology is required to pinpoint specific sources of these parasites in environmental water samples.

Implications and Recommendations

Before this study began, little was known about protozoan parasites in a large northern river basin. As with many studies that are essentially "breaking new ground", more questions were raised than were answered. Findings from this study do suggest that livestock in the watershed are a major contributor to levels of parasites in the river. However, other sources also contribute, and statistical relationships need to be confirmed with further detailed study. Because potential sources of these organisms are present throughout the watershed, additional sampling would be needed to measure direct linkages between livestock and parasite levels in streams.

Alberta's Agriculture Industry

Alberta has the largest beef industry in Canada. The Alberta beef industry should be a leader in applying measures to reduce their impact on the environment. We recommend that runoff from livestock operations be managed so that impacts on surface water can be minimized.

Beneficial Management Practices should be evaluated for Alberta to assess how well they reduce sources of parasites and other contaminants that may affect surface waters. Research into ways to reduce parasite infections in cattle is needed. This could benefit Alberta producers by reducing scours and mortality. As well, the beef industry should continue their efforts in educating producers on environmentally sustainable practices through extension materials, seminars and workshops. These measures should reduce concentrations in drinking water and therefore the risk to public health.

Additional sampling should be done on creeks above and below cattle operations, including beef and dairy. These sites should be tied in to management practices used on the farm. More intensive sampling should be done along streams draining agricultural watersheds to identify areas that contribute disproportionately to parasite loads in tributary streams.

Municipal Wastewater

Sewage treatment plant operators need to understand their contribution to parasite concentrations in the river. A study should be done to evaluate how different treatment technologies remove parasites from wastewater. Treatment facilities that allow a large percentage of organisms to pass through may need to upgrade their operation. The presence of both parasites in all effluents monitored suggests that some people in the basin are infected. Public health authorities may wish to determine the extent of infections. A data gap that should be addressed is the contribution of parasites and other contaminants from private sewage disposal systems, especially those that discharge to the surface.

Drinking Water Treatment

Cryptosporidium and giardia in surface water are a risk to human health when the water is used as a raw water source for drinking. The risk is low if treatment plants are operating effectively. However, the water treatment process can be compromised during peak runoff periods such as spring runoff and following heavy rainfall when contaminant loads, including parasites, in the river are high. It is at these times that the risk of parasites getting through to the treated water supply is greatest.

Each plant in the basin should be assessed to determine how well parasites are removed. Drinking water treatment plants should be designed or upgraded to cope with actual levels of parasites in the source water. Because small treatment facilities are not required to monitor parasites in raw or treated drinking water, they typically do not include monitoring costs in their budgets. Therefore, the Alberta government should set standards for these parasites similar to those of the United States Environmental Protection Agency, as well as collect and analyze samples during runoff periods.

At present, drinking water treatment operators must assume that all protozoan parasites in their raw water supply are potentially infective. Further research is needed to develop methods for assessing whether organisms are alive and which species are infective to humans.

Wildlife Management

Although the prevalence of giardia in beaver and muskrat was fairly high, control of these animals on streams is not practical. However, to reduce the transmission among aquatic mammals, livestock and humans, removal of these aquatic rodents from dugouts that are used as drinking and watering supplies may be warranted.

High concentrations of parasites were present in samples from the non-agricultural streams during summer runoff periods. Although the breaching of beaver dams likely contributed to these concentrations, additional study should be done of other sources in non-agricultural watersheds. As well, sediments on the bottom of beaver ponds and creeks should be sampled to determine whether they retain parasites until washed out during high flows.

In summary, this research program has illustrated the complexities associated with identifying watershed sources of waterborne parasites. Watershed streams and wastewater effluents contribute to levels of parasites in the North Saskatchewan River. We recommend that all watershed stakeholders, including wastewater operators, drinking water treatment plant operators, livestock producers, rural residents and other landowners and industries work together to reduce the impact that all land uses have on the water quality of the North Saskatchewan River. Support is required from provincial and municipal governments as well as private landowners and the agricultural industry to assist watershed and community groups in implementing water quality protection programs.

Glossary

Note: the terms listed here are defined as used in the report. Some may have more general meanings.

Animal unit equivalent. A conversion factor based on the relative size of an animal and therefore the amount of manure produced. It is the same as the MU Reciprocal in the 2000 Code of Practice[1]

Chemicals. Water quality is assessed by measuring a variety of chemical substances (as well as biological and physical characteristics). All matter is composed of chemicals – even water (the familiar H_2O). Most of the chemicals in water are natural, such as calcium, sodium and bicarbonate.

Concentration. The amount of a substance in a known volume of water, e.g. number of parasites per 100 L or milligrams per litre of a chemical substance.

Confined feeding operations. A type of livestock operation that houses and feeds a large number of animals. The number of animals depends on the type of livestock. Used to be called Intensive Livestock Operations.

Contaminant. Any substance that degrades water quality. It usually refers to toxic or otherwise harmful substances.

Cryptosporidiosis, giardiasis. Diseases caused by protozoan parasites.

Load, Mass Load. The amount of a substance in a stream over a given time (e.g., kilograms or organisms per second, day, etc.). It is calculated by multiplying the concentration by the flow rate of the creek.

Non-point source pollution. Pollution from diffuse land sources, transported by runoff.

Parasite. An organism that absorbs nutrients from the body fluids of living animals.

Point source pollution. Pollution from specific well-defined sources, such as an effluent discharge pipe from a sewage treatment plant.

Pollution. The contribution of substances from human activities that may adversely affect a desired use of water.

Prevalence. The percentage of samples containing organisms; commonness.

Protozoa. *Singular, protozoan.* Single-celled animals which belong to a diverse group of organisms called protists (Kingdom Protista). Protozoa are animal-like, in that they ingest food.

Runoff. Water that moves across (or through) soils on the land during snowmelt or rainstorms.

Tributary. A smaller stream that flows into a larger one.

Turbidity. Cloudiness of the water. Turbidity is caused by tiny particles of soil, organic matter. and other materials that are picked up by flowing water.

Water Quality. The chemical, biological and physical characteristics of water, usually with respect to its suitability for a particular purpose.

Watershed. Land that slopes down toward a creek or river, and thereby drains runoff from it. A large watershed like the North Saskatchewan River Basin contains many smaller watersheds.

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[1]2000 Code of Practice for Responsible Livestock Development and Manure Management, (Alberta Agriculture Food and Rural Development, 2000)