Assessment of Simple Filter Systems for Treating Run-Off From Seasonal Livestock Areas

Alan Stewart[1], Sharon Reedyk[1], and George Chu[1].

[1]Prairie Farm Rehabilitation Administration, Agriculture and Agri-Food Canada, Edmonton, AB, T5J 4C3

Abstract

Cattle wintering sites and calving grounds are frequently located on dissected terrain. In many of these areas there is a high risk of contamination to stream headwaters from on-site run-off, particularly in the spring. A literature review suggested a number of small- or municipal-scale filter treatments that may have potential for treating run-off in terms of reducing nutrient and pathogen concentrations. If effective, such systems may provide a low-cost, low-maintenance system for treating run-off in these situations.

A two-year bench scale trial was initiated in 2006 at two sites to test the effectiveness of four filter technologies. The technologies were chosen based on several criteria which included: capital and maintenance costs, simplicity, known effectiveness, space requirements, and the ability to scale down the technology. The four selected filters were: demand-operated slow sand filter, intermittent flow sand filter, intermittent flow wood chip filter, and continuous flow rock filter.

The trial and filters are described and preliminary results obtained starting in July, 2006 are presented. First year results suggest that the slow sand filter is not a viable technology but the intermittent flow filters and the rock filter show promise.

Introduction

Cattle production is an important part of the agricultural industry in the prairie region. There are two main parts to the industry. The feedlot component is characterized by the large, intensive finishing operations. The other component is the smaller purebred, cow-calf and backgrounding operations that support the feedlots. They are primarily forage-based operations and tend to be more extensive. As well as being smaller, these operations tend to be distributed in rougher landscapes that are less suitable for crop production. However, during winter feeding and calving high numbers of livestock may be confined in quite small areas, and often the areas are chosen to provide shelter and access to water. These seasonal livestock holding areas may be a significant source of manure-enriched run-off. These areas are also frequently in which the headwaters of streams, and by association there is a high risk of run-off affecting streams water quality and downstream waterbodies.

Given the risk of headwater contamination by these sites our interest was in finding a method of managing or treating run-off to protect stream water quality. The work was started in conjunction with Dr David Manz who conducted a review of current practices and small scale treatment systems to get a preliminary evaluation of what may be feasible (Manz, 2006, 1). The review confirmed many of the existing best practices including:

- control of run-on to the site in order to minimize run-off,
- effective channelling and collection of run-off from the entire site, and
- retention of run-off in a stabilization reservoir or lagoon.

In our prairie climate the most consistently timed, and usually the largest, run-off event is spring snowmelt. The stabilization / storage reservoir is an integral part of the treatment train to hold run-off from short-duration, high-volume events, and to retain the run-off until seasonal temperatures rise and allow biologically based treatments to function.

The review also indicated that a number of domestic or small-scale municipal treatments may be effective in treating the effluent from the stabilization reservoir (Table 1).

Table 1. Domestic / Municipal Waste Treatments

Soil Absorption Fields
Mound Systems
Septic Systems
Low-Pressure Pipe Systems
Rock Filters
Slow Sand Filters
Intermittently Dosed Packed Filter Bed (Sand / Peat) Filters
Recirculating Intermittently Dosed Packed Bed Filters
Trickling Filters
Anaerobic Reactors
Chemically Enhanced Primary Treatment

A general assessment of prairie factors such as climate regime, run-off water volumes and quality, site conditions and size indicated that small-scale systems may be able to handle and treat the normal amounts of run-off from seasonal livestock holding areas. Thus the idea of developing a low-cost, low maintenance treatment seemed promising.

Based on these findings, Dr Manz designed a bench-scale trial (Manz, 2006, 2). The design recommended testing pre-stabilization filtering and pre-release filtering (Figure 1). However, for the initial study we chose to undertake a bench-scale pilot project using existing stabilization ponds. The trial addresses only pre-release filters employing media that is generally readily available and included:

- Intermittently dosed packed bed filter, sand media
- Intermittently dosed packed bed filter, wood media
- Continuously dosed rock filter, and
- Demand operated slow sand filter.

This paper reports preliminary results from the bench-scale tests of four filters at two sites in the summer of 2006.

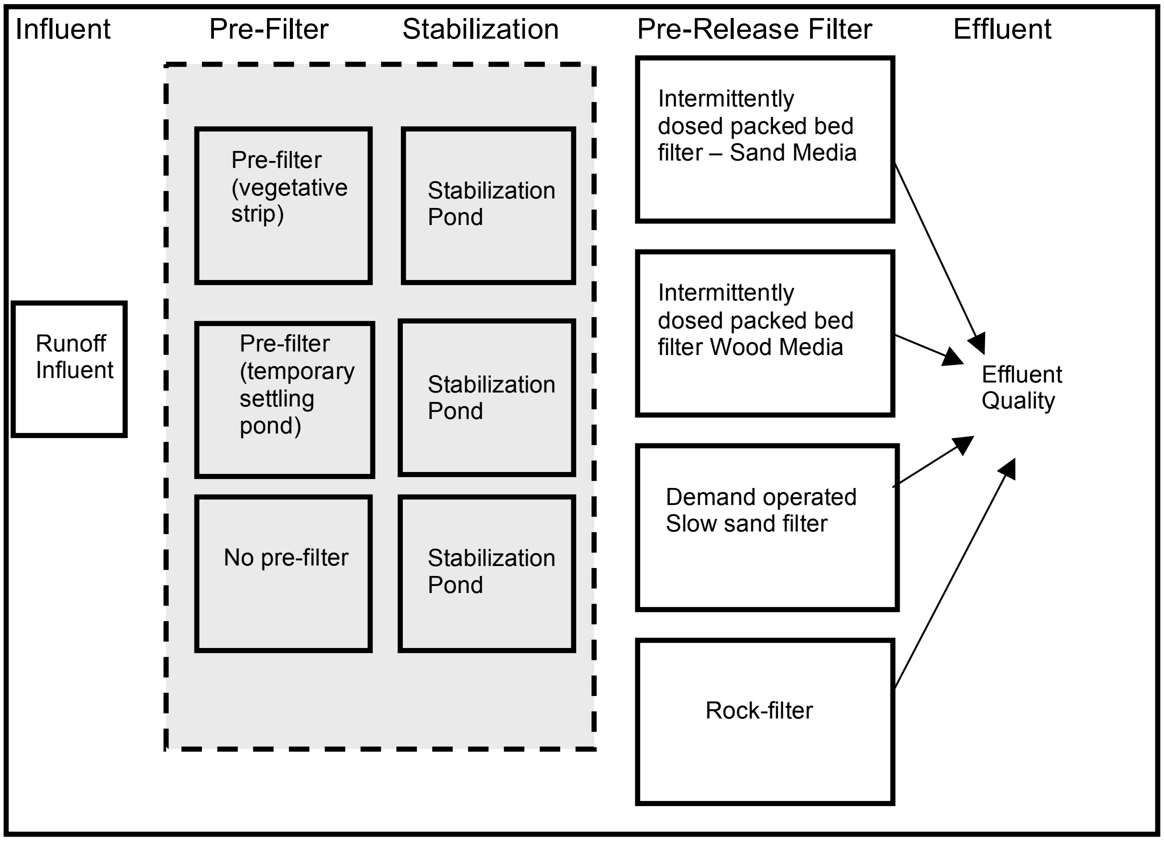

Figure 1. Recommended Trial Treatment Trains for a Total System Trial

Materials and Methods

Filter media were chosen for testing on the basis of being readily available locally in prairie locations. The general operating conditions were established (Table 2) on the basis of standard operating practices for the filter type adjusted for the bench-scale trial.

Bench-scale trials of the filters were established at two sites, one near Edmonton, Alberta and the second near Dawson Creek, BC (Table 3).

Once set-up, both sites were sampled weekly. The Dawson Creek site was sampled for 10 weeks starting July 25, and the Edmonton site for 8 weeks starting August 15. Samples taken included water taken from the stabilization reservoir (the filter influent water) and water that had passed through each of the filters (effluent waters). Standard water sampling practices were used and samples were analyzed at a commercial laboratory (ALS labs in Edmonton, Alberta) for a suite of parameters reflecting physical, chemical and microbiological qualities.

Table 2. Test Filter Characteristics and Operating Rates

Filter	Dimensions	Flow Type	Flow Rate
Intermittent Sand Filter (ISF)	90 cm diameter; 110 cm deep	Intermittent	5 L/hr applied at 1 L/minute for 5 minutes every hour
Intermittent Wood Chip Filter (IWF)	90 cm diameter; 110 cm deep	Intermittent	5 L/hr applied at 1 L/minute for 5 minutes every hour
Rock Filter (RF)	75 cm deep x 90 cm wide x 15 m long	Continuous	0.3 L/minute
Slow Sand Filter (SSF)	60 cm diameter; 100 cm deep	On - demand	0.5 L/minute

Table 3. Summary of Filter Test Set-Up and Operation, 2006

2 sites Edmonton (Nowicki)
Dawson Ck (Wilson)

4 Filters Slow sand filter, continuous flow (SSF)
Intermittent sand filter, masonry sand (ISF)
Intermittent wood filter, commercial wood chips (IWF)
Rock filter, 2.5+ cm stone, continuous flow (RF)

Sampling weekly to the end of the season

Dawson Creek started July 25 – 10 sampling dates
Edmonton started August 15 – 8 sampling dates

13 Water Quality Parameters

Turbidity, Colour, Conductivity, pH, TSS
Total P, Dissolved P
TKN, NOx-N, NH_4^+-N
BOD
E. Coli, Fecal Coliforms

The Dawson Creek site (Figure 4) illustrates the trial set-up.

Figure 4. Overview of the Trial at the Dawson Creek Site.

The source stabilization pond is in the background. The white round barrels are (l to r) the intermittently dosed sand filter (ISF), the intermittently dosed wood chip filter (IWF), and the slow-sand filter (SSF) The three rectangular containers are connected in series and together are the continuous-flow rock filter. The table on the right supports the control manifold regulating the influent to the filters. The blue barrel is not part of the trial.

Results and Discussion

Pre-Treatment (Influent) Water Quality

The water quality of the raw water influent from the stabilization reservoirs was quite different at the two sites, with the Edmonton site having much higher values compared to the Dawson Creek site (Table 4). This spread in water quality values provided the range over which the filters were tested. The results of filtration were compared at the two sites and were also compared to standards taken for water treatment systems and recreational water quality standards.

Table 4. Raw Water Quality Parameters of the Edmonton and Dawson Creek Sites

	Edmonton (mean of 8 samples)	**Dawson Creek (mean of 10 samples)**
Total Suspended Solids (mg/L))	142	3
Biological Oxygen Demand (mg/L)	35	6
E. coli (CFU/100 ml)	177	51
TN (mg/L	52	8
TP (mg/L)	12	0.6

Biological Oxygen Demand (BOD) (Table 5).
The Edmonton raw influent value (36 mg/L) was above the target of 25 mg/L and the Dawson Creek value (6 mg/L) was substantially below the target. At Edmonton the ISF significantly lowered BOD and at Dawson Creek both the ISF and RF significantly lowered BOD. The wood chip media of the IWF may have contributed to slightly higher BOD in the effluent from those filters.

***E. coli* (Table 5)**
Raw water E. coli levels were below target levels at both sites. At the Edmonton site the ISF effluent had increased E. coli and other filters' effluent was not different from the raw influent. At Dawson Creek, effluents from the ISF had lower, and from the IWF had higher levels than the raw water. The RF and SSF results were not significantly different than the raw water.

Table 5. Mean Biological Oxygen Demands (BOD) and E. coli Concentrations in Raw Influent (RAW) and of the Effluents the Intermittent Sand Filter (ISF), Intermittent Wood Filter (IWF), Rock Filter (RF) and Slow Sand Filter (SSF), 2006.

	RAW	**ISF**	**IWF**	**RF**	**SSF**
EDMONTON					
BOD (mg/L)	35.13	18.63*	42.88	41.38	30.75
E. coli (CFU/100ml)	177	27,272*	244	149	356
DAWSON CREEK					
BOD (mg/L)	5.90	2.40*	8.90	2.40*	6.20
E. coli (CFU/100ml)	51	3*	2652*	6	12

Nitrogen (Table 6)
Total Nitrogen was significantly reduced by the IWF at the Edmonton site and by both the IWF and RF at the Dawson Creek site. The ISF and SSF were not effective at either site. *Kjeldahl Nitrogen* was significantly reduced by the ISF, IWF and RF at both sites. Again the SSF was not effective at either site.

Ammonia reductions by filtration were similar at both sites and, possibly because ammonium makes up a large part of Kjeldahl-N, the reductions were similar to those for Kjeldahl-N. The target for reduction was 60% and the ISF and IWF exceeded the target at both sites. At Dawson Creek the RF was effective but it did not work well at the Edmonton site. The SSF performed poorly at both sites.

Nitrate+Nitrite levels at both Edmonton and Dawson Creek were much higher in ISF compared to raw water levels. At Dawson Creek the IWF and RF had reduced Nitrate + Nitrite but at Edmonton there was no improvement.

Table 6. Mean Nitrogen Levels in Raw Influent (RAW) and of the Effluents the Intermittent Sand Filter (ISF), Intermittent Wood Filter (IWF), Rock Filter (RF) and Slow Sand Filter (SSF), 2006.

	RAW	**ISF**	**IWF**	**RF**	**SSF**
			EDMONTON		
Total-N (mg/L)	52.11	52.57	28.09*	38.88	45.67
Kjeldahl-N (mg/L)	52.05	27.30*	27.99*	37.99*	45.61
NH4+-N (mg/L)	21.77	4.30*	7.28*	20.33	28.44
NO3&NO2-N (mg/L)	0.06	25.27*	0.11	0.89	0.06
			DAWSON CREEK		
Total-N (mg/L)	8.17	8.70	4.26*	4.00*	7.37
Kjeldahl-N (mg/L)	6.60	3.63*	4.15*	3.94*	6.05
NH4+-N (mg/L)	2.81	0.27*	0.48*	0.71*	2.09
NO3&NO2-N (mg/L)	1.57	5.07*	0.11*	0.06*	1.32

Phosphorus (Table 7)

Total Phosphorus and Dissolved Phosphorus reductions had similar patterns. P reductions at both sites were similar, the IWF and ISF having the best results, then the RF. There were no reductions by the SSF at either site.

Table 7. Mean Phosphorus Levels in Raw Influent (RAW) and of the Effluents the Intermittent Sand Filter (ISF), Intermittent Wood Filter (IWF), Rock Filter (RF) and Slow Sand Filter (SSF), 2006.

	RAW	**ISF**	**IWF**	**RF**	**SSF**
			EDMONTON		
Total-P (mg/L)	11.6	7.10*	6.18*	8.48*	10.07*
Soluble-P (mg/L)	8.36	6.62*	5.36*	7.93	9.60
			DAWSON CREEK		
Total-P (mg/L)	0.58	0.17*	0.16*	0.22*	0.51
Soluble-P (mg/L)	0.53	0.15*	0.14*	0.17*	0.47

Conclusions

The literature review reinforced the value of existing best practices including run-on and run-off management, pre-storage filtration and storage of run-off in a stabilization pond. In our climate use of a storage pond is essential to hold spring run-off until seasonal temperatures rise to levels that allow for biologically based treatments to be effective.

The review also indicated that there are a variety of relatively simple municipal filter treatments that may be adapted for treating agricultural run-off. There are potentially a wide variety of suitable filter media and at least some media should be locally available everywhere.

The trial to date indicates the SSF (slow-sand filter) is probably not suitable for treating the quality of effluent from run-off. The slow sand filter used was designed as a polishing treatment for potable water and it does not appear to be able to handle the relatively low quality effluent used in the trials.

The rock filter and intermittent sand and wood filters show good promise. There are some differences between the filter performances and further work may suggest that a combination of filter media may be the best solution.

References

Literature Review to Assess the Feasibility of a Filter System to Treat Runoff from Seasonal Livestock Holding Areas. January 31, 2006. Dr. David H. Manz, P. Eng.

Development of Designs to Pilot Treatment-Train Alternatives to Treat Run-off from Seasonal Livestock Holding Areas. March 31, 2006. Dr David H. Manz, P.Eng.