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EVALUATION OF MANURE TREATMENT SYSTEMS FOR LIVESTOCK OPERATIONS

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EVALUATION OF MANURE TREATMENT SYSTEMS FOR LIVESTOCK OPERATIONS

Final Report

Submitted to:

Livestock Water Recycling, Inc.

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Olds College Centre for Innovation

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Introduction

IWR Technologies Ltd is a privately owned Canadian company with over twenty years of experience building and deploying wastewater treatment systems across North America. For the past 7 years IWR has been examining manure management and agricultural waste water treatment. The result of this is Livestock Water Recycling, Inc. (LWR), the wholly owned subsidiary of IWR Technologies focused on water treatment for the livestock industry.

In 2006 LWR implemented a proprietary technology at a hog CAFO in Alberta. The encouraging results led to the development of this patent pending process. The influent into the LWR System is comprised of mixed manure liquids that come directly from the barns housing the livestock. The manure-rich wastewater flows initially through a solids separating screen system, a specially designed fine solids separation tank, through multi-media filters, and lastly a membrane filtration system. As the wastewater flows through the process, solids are removed from the influent stream and concentrated for use as fertilizer. The clean discharge water is available for reuse in the barns.

With the application of an LWR system a livestock operation can create a value added fertilizer, and close-loop its water use thus reducing ponds/lagoons, nuisance odour complaints, costs associated with nutrient management, and difficulties with land/water permit applications. The fertilizer material generated by the LWR system is available for use or for sale. The system produces two forms of fertilizer. One is a sludge/solid rich in organic forms of nitrogen and phosphorus. The other is a liquid concentrate of ammonium salts and potash. It was our hypothesis that the sludge produced by this system could be useable in bioenergy production.

The CAFO 'pollutants of concern' are total nitrogen (ammonia, nitrite/nitrate, and organic nitrogen), total phosphorus, total suspended solids (TSS) and biochemical oxygen demand (BOD5). These parameters were selected because of their high concentrations in manure-type waste streams and their impact on surface water quality if not treated. Subsequently the samples were submitted to Olds College Center for Innovation (OCCI) lab facilities to test:

(1) The concentration of contaminants in the manure entrained wastewater from each site sample

(2) the cleanliness and reusability of the clean water after processing through an LWR system, including sampling for hormones and/or antibiotic contamination utilizing standard water quality tests performed on each site sample (BOD, EC, pH, TDS, TSS, Total and fecal coliforms and *Escherichia coli*)

(3) The suitability of solid and liquid by-products of the system as fertilizer (standardized analysis for fertilizer and subsequent determination of potential crop usage).

Additionally OCCI staff and students performed research on bioenergy production from manure to indicate how the LWR system could be most efficiently employed in this capacity. This required additional lab work to determine the volatility of the by-products (sludge/solids) of the system to evaluate the potential for use in energy production.

Objectives

The objectives of the proposed work were to test the water quality at various points of the onsite manure concentration process and perform an assessment of the suitability of the treated water for use within the livestock operation. The testing includes an assessment of the concentration of chemicals in the wastewater, the cleanliness and reusability of the water in terms of CCME standards for livestock purposes and the suitability of the solid and liquid by-products as fertilizer.

The following objectives were achieved:

- Determination of hormones and/or antibiotic contamination as well as standard water quality tests including: BOD, EC, pH, TDS, TSS, Total and fecal coliforms and *E. coli*,
- Determination of the suitability of solid and liquid by-products of the system as fertilizer through the standardized analysis for fertilizer,
- Compostability of by-products (sludge/solids) of the system and nutrient quality of composted by-products (sludge/solids) as fertilizer and indicate how the LWR system could be most efficiently employed in this capacity, and
- Biogas production potential of manure.

Materials and Methods

1. Water sampling and testing of water quality at the different points in the process system

Five sampling points were identified for sampling in the water recycling process onsite. The five sites selected for sampling are as follows:

- Process sample site A –Influent
- Process sample site B – Fertilizer solids
- Process sample site C – Watery sludge fertilizer
- Process sample site D – Dissolved solids removal
- Process sample site E – Effluent

The water samples from sites A, D and E were collected following standard water sampling protocol and sent to a commercial lab, Exova in Calgary. The samples were collected in prescribed sampling bottles with and without preservatives as required for the type of testing selected for each sample. The test methods and results for each sample are shown in Appendix A.

Results and Discussion

The samples from the different sampling sites of the water recycling process at LWR facility were used for assessing the water quality for livestock water reuse and their potential for biogas generation and compostability for added value of the fertilizer wastes.

The entire quality of the water and manure samples collected from the five different sample points (A-E) of the process is given in Table 3. This gives an overview of the quality of the products and by-products of the process.

The results of this project will be discussed under the following categories: 1) water quality, 2) compostability testing and 3) biogas production.

1. Water quality of the recycled water for livestock water supply

The water quality analysis for the reuse of the recycled livestock watering was done for the samples A, D and E representing outlets after each of the different treatment processes involved in the recycling process as shown in Appendix B.

The results of the water tested for micronutrients and metals are given in Tables 3 and 4. The overall quality of the water is good, with no physical abnormalities. The physical parameters of the samples are given in Table 4.

Table 3: Metals and Non-metals in samples from various points of the livestock water processing.

Sample Description	Process Sample A Influent / 4.4C	Process Sample B Concentrated Manure	Process Sample C Solids Removed Liquid Manure	Process Sample D Routine / 4.4C	Process Sample E Effluent / 4.4C	CCME Irrigation (mg/L) Water Quality Guidelines for the Protection of Agriculture	CCME Livestock (mg/L) Water Quality Guidelines for the Protection of Agriculture	Nominal Detection Limit
Inorganic Nonmetallic Parameters								
Ammonia - N mg/L	1140	2600	700	2820	18.2			0.05
Kjeldahl Nitrogen Total mg/L	1690	5100	700	3290	20.5			0.06
NH4 - mg/L		2600	692					
Unionized NH3 - mg/L			8.4					
Phosphorus Total mg/L	164	3700	< 100	1.24	<0.05			0.05
Organic Carbon Total Nonpurgeable mg/L	2450	49000	1000	3570	2.3			0.5
Carbon:Nitrogen Ratio	1.45	9.60		1.09	0.11			
Metals Total								
Calcium Total mg/L	342			240	<0.4	No Data	1000	0.2
Beryllium Total mg/L	<0.001			<0.002	<0.0002	0.1	0.1	0.0001
Mercury Total mg/L	<0.0001		< 0.1	<0.0001	<0.0001	No Data	0.003	0.0001
Cobalt Total mg/L	0.015		< 1	0.02	<0.0002	0.05	1	0.0001
Lead Total mg/L	0.027		< 1	<0.002	<0.0002	0.2	0.1	0.0001
Molybdenum Total mg/L	0.06		< 1	0.1	<0.002	Narrative *	0.5	0.001
Arsenic Total mg/L	0.011		< 1	<0.005	<0.0004	0.1	0.025	0.0002
Boron Total mg/L	0.59			0.88	0.246	Variable	5	0.002
Cadmium Total mg/L	0.0032		< 0.5	<0.0002	<0.00002	0.0051	0.08	0.00001
Chromium Total mg/L	0.187		< 1	0.01	<0.001	0.008	0.05	0.0005
Nickel Total mg/L	0.105		< 1	0.18	<0.001	0.2	1	0.0005
Selenium Total mg/L	0.022		< 1	<0.005	<0.0004	Variable **	0.05	0.00002
Uranium Total mg/L	0.036			<0.01	<0.001	0.001	0.2	0.00005
Vanadium Total mg/L	0.037			0.003	0.0002	0.1	0.1	0.0001
Zinc Total mg/L	7.12		< 2	0.1	0.002	Equation	50	0.001
Copper Total mg/L	1.05		< 1	0.03	<0.002	Variable	Variable	0.001
Potassium as K2O mg/L			< 1200					
Aluminum Total mg/L	14			0.35	0.02	5	5	0.005

* The concentration should not exceed 10 µg/L for continuous use on all soils, or 50 µg/L for short-term use on acidic soils

**Selenium = 20 ug/L for continuous use on all soils
= 50 ug/L for intermittent use on all soils

Copper = 200 ug/L for cereals
= 1000 ug/L for tolerant crops
= 500 ug/L for sheep, 1000 ug/L for cattle, 5000 ug/L for swine and poultry

Zinc = 1000 ug/L when soil pH < 6.5
= 5000 ug/L when soil pH > 6.5

Table 4: Micronutrients and physical parameters in samples from various points of the livestock water processing.

Sample Description	Process Sample A Influent / 4.4C	Process Sample B Concentrated Manure	Process Sample C Solids Removed Liquid Manure	Process Sample D Routine / 4.4C	Process Sample E Effluent / 4.4C	CCME Irrigation (mg/L) Water Quality Guidelines for the Protection of Agriculture	CCME Livestock (mg/L) Water Quality Guidelines for the Protection of Agriculture	Nominal Detection Limit
Routine Water								
pH	7.81	7.1	7.61	4.79	9.1			
Temperature of observed °C	20.6			20.5	20.4			
Ash mg/L		283000						
Organic Matter mg/L		717000						
Moisture - %		86	99.7					
Electrical Conductivity µS/cm at 25 °C	11700	7.42	8.1	36000	256 1			1
Calcium Dissolved mg/L	57 176	5400	100	<0.2	0.2			0.2
Magnesium Dissolved mg/L	28 135	1100	< 100	<0.2	0.2			0.2
Sodium Dissolved mg/L	758	400	500	3480	12.3			0.4
Potassium Dissolved mg/L	412	< 1000	< 1000	1090	4			0.4
Iron Dissolved mg/L	0.16			0.98	0.01			0.01
Manganese Dissolved mg/L	0.23			2.15	<0.005			0.005
Chloride Dissolved mg/L	875			4340	18.8			0.4
Nitrate - N mg/L	1.3	< 10000		<0.5	<0.01			0.01
Nitrite - N mg/L	<0.1			<0.2	<0.005			0.005
Nitrate and Nitrite - N mg/L	1.3			<0.7	<0.01			0.01
Phosphorus as P2O5 mg/L			< 200					
Sulfur Total mg/L			400					
Sulfate (SO4) Dissolved mg/L	994			6520	12			0.9
Hydroxide mg/L	<5			<5	<5			5
Carbonate mg/L	<6			<6	<6			6
Bicarbonate mg/L	4620			1130	88			5
P-Alkalinity as CaCO3 mg/L	<5			<5	<5			5
T-Alkalinity as CaCO3 mg/L	3790			925	72			5
Total Dissolved Solids Calculated mg/L	6540			19100	96		3000	1
Hardness Dissolved as CaCO3 mg/L	260			995	2			
Ionic Balance Dissolved %	108			145	92			

With the exception of phosphorus, tests for ammonia, nitrogen and organic carbon were more concentrated in samples collected after dewatering as compared to samples tested prior to any processing.

A greater concentration of water soluble salts is evident in sample D after the dewatering step which may indicate water soluble salt retention and concentration in the water. But with the reverse osmosis treatment prior to the sample point E, the concentration of the salts are drastically reduced, making it fit for use as drinking water as per CCME standards.

Table 5: Analysis of pesticides/hormones in effluent water sample E.

Name	Category	Molecular weight	MS/MS pattern
Progesterone	Hormone	315	297.3/279.1
Estradiol	Hormone	272	159.1/133.0
Chlorpyrifos	Pesticide	314	258
Bupimirate	Pesticide	273	193
S,S,S-tributyl phosphorotrithioate (DEF)	Pesticide	314	169

Testing at Grant MacEwan University was completed to determine the presence of specific hormones and pesticides in sample E. Due to the low levels, this sample was concentrated 100 times to accurately detect the presence of these compounds. All samples shown in Table 5 were present, although minute. Further quantification of these compounds will better determine the impact these compounds have on the environment.

The microbiological analysis of sampling points at A and E indicate that there was high contamination levels of fecal coliforms and *E.coli* at sample A associated with the influent water laden with manure and other possible contaminants. The second sample of the effluent site, sample E, indicates that the microbial contaminants had been effectively removed by the membrane filtration and the reverse osmosis processes included as part of this treatment stage.

The water requirement and intake in livestock may vary depending on species and breeds of livestock, animal status, production mode, environment or climate in which livestock are raised. All these variables are directly or indirectly relevant to several aspects of water metabolism and physiology.

The existing CCME water quality guidelines are developed only for the protection of the animal and do not address potential accumulation of contaminants that may be passed on to consumers through milk or meat. Accumulation of the contaminant from other sources, such as feed is sometimes addressed, often with the addition of a safety factor of about five times. The variability in sensitivity for different species and life stages is addressed by basing the livestock drinking water quality guidelines on the most sensitive species at its most sensitive life stage (i.e. to safeguard animal health). An uncertainty factor is often applied based on the quality and extent of the data. Antagonistic or synergistic aspects between various contaminants are rarely addressed as these factors complicate an already complex and challenging guideline derivation. Succinctly stated, synergistic effects of multiple contaminants in water, feed and environmental exposure, is not well understood.

The goal of a guideline in livestock drinking water is to ensure that concentrations of contaminants less than the guideline will ensure no significant health or production effect. The samples A, D and C representing the subsequent sampling ports in the LWR technology in water recycling for livestock reuse, depicted that a reliable contamination removal system is in place. The water sample E at the effluent point meets the CCME where data is sparse or lacking, guidelines may be based on protocols used for assessment of drinking water standards for humans.

Several water quality parameters such as pH, salinity, odor, taste etc., may affect palatability. Contaminants in water may affect intake of both water and feed, but the responses may vary depending on specific metabolic features of animals.

Earlier work has shown that high sulphate levels in water significantly decreased water intake in cattle (Weeth and Hunter, 1971). Reduction of TDS in water from about 4,400 to 440 mg/L resulted in increased water intake and feed intake. If water quality affects feed intake, reduced feed consumption may affect performance (Weeth and Capps, 1972; Loneragan, *et al.*, 2001). Moreover, the specific features of sulphur metabolism in ruminants may result in a wide range of metabolic effects associated with high levels of sulphate in drinking water.

On the other hand, in animals that do not metabolize water contaminants such as sulphate, the responses may be completely different. For example in weanling pigs offered high TDS and sulphate drinking water, the intake of water actually increased, and no overt metabolic effects were observed.

Intake of many elements that are excessive in water can be effectively managed through appropriate ration formulation. Thus, a solid understanding of the specific regional issues of water quality for livestock is important.

The problem of water contaminants in livestock should be recognized as early as possible, and definitively before the signs of adverse health effects are showing. Both producers and water specialists ought to be trained on how to recognize subtle adverse effects on growth rate, feed conversion ratio, reproductive success, milk yield, and product quality.

The importance of interactions of water contaminants with factors such as production mode or the nutritional and physiological status of the animal must be fully appreciated. In order to understand and recognize subtle problems resulting from water quality in livestock, it is important to understand how water contaminants affect physiological and biochemical parameters.

The current water quality guidelines provide recommendations of values for each contaminant. However, it is important to stress, that in view of the current knowledge, the effects of individual water contaminants cannot be deliberated as a "stand alone" problem, but rather must be considered in the context of complex interactions with other dietary and/or environmental variables with a strong analytical emphasis on the potential adverse effects resulting from:

- cumulative effects
- additive effects
- synergistic effects

Furthermore, it is important to understand that the risk of adverse effects associated with any particular individual contaminant in the water should not be dismissed based exclusively on a perceived safe concentration in water. This is because if the same factor is also present in the feedstuffs, along with the water contribution, the cumulative content of this contaminant may exceed the threshold and trigger metabolic or even toxic effects.

Conclusion and Recommendations

Water Quality for Animal Water Use

The physical and chemical quality of the recycled water is deemed suitable for livestock water reuse as per CCME standards. The microbial quality of water is also acceptable. The hormone and pesticides in the effluent water was detected after a 100x concentration indicating very negligible amounts. The recycled water needs to be frequently tested for metals and minerals which may vary depending on feeding practices to maintain its quality and avoid issues of bioaccumulation. Feeding conditions influence manure and waste water quality of livestock operations. Further investigation into feeding strategies can be done to optimize the quality of byproducts. Carbon sequestration techniques like micro algae culture to trap biogas can be looked into to lower greenhouse gas emissions for achieving low carbon credit operation accreditation.

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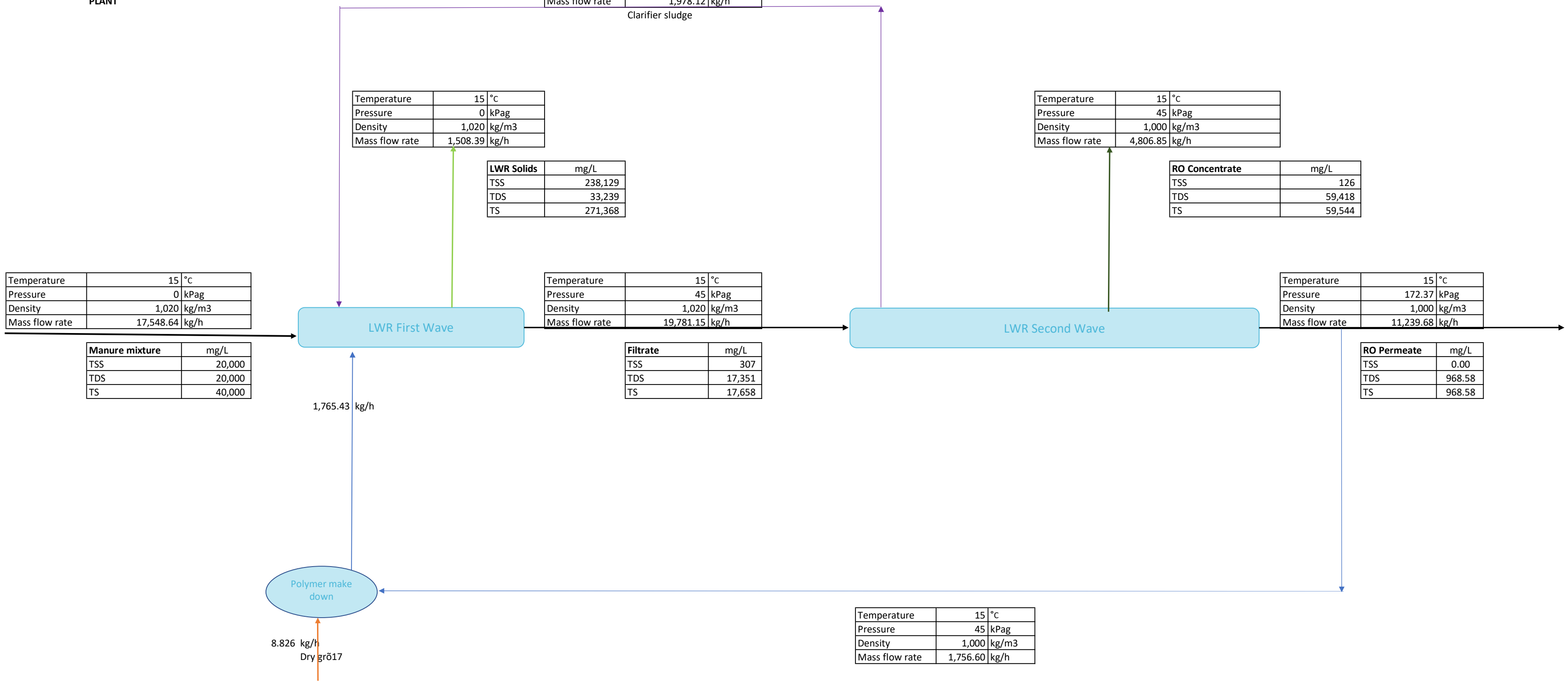
MAINTENANCE TASKS

FIRST WAVE MAINTENANCE TASKS	DAILY	WEEKLY	MONTHLY	ANNUALY	EVERY 2 YEARS
Drain and clean filtrate tank V-170	X				
Inspect to make sure all polymer distribution lines are clear and free flowing	X				
Inspect screen for tears or damages	X				
Drain and clean screw press liquid tank V-130	X				
Check and grease bearings (MicroScreen chain drive)		X			
Check gearbox oil level		X			
Check/clean grōControl sensors	X				
Check spray nozzles, clean as required	X				
Clean level switch in V170	X				
Enter log sheet **data into system**	X				
Change gearbox oil				X	
Clean screw press			X *as required*		
Optimize floc tank mixer speed		X			
Oil change on screw press gearbox					X
Grease screw press			X		
Grease pillow block bearings			X		
SECOND WAVE MAINTENANCE TASKS	DAILY	WEEKLY	MONTHLY	ANNUALLY	EVERY 2 YEARS
Drain and clean the Clarifier (V-190)		X			
Replace Cartridge Filter Cartridges		X *as required*			
RO Cleaning (AutoClean Process)	X				
RO Manual Cleaning		X *as required*			
P-210 Descaling				X *as required*	
Probe RO Vessels	*As-Required When Permeate Quality Deteriorates*				

Appendix A
Newtrient Mass Balance
PLANT



Clarifier sludge

Temperature	15	°C
Pressure	45	kPag
Density	1,020	kg/m3
Mass flow rate	1,978.12	kg/h

Temperature	15	°C
Pressure	0	kPag
Density	1,020	kg/m3
Mass flow rate	1,508.39	kg/h

LWR Solids	mg/L
TSS	238,129
TDS	33,239
TS	271,368

Temperature	15	°C
Pressure	45	kPag
Density	1,000	kg/m3
Mass flow rate	4,806.85	kg/h

RO Concentrate	mg/L
TSS	126
TDS	59,418
TS	59,544

Temperature	15	°C
Pressure	0	kPag
Density	1,020	kg/m3
Mass flow rate	17,548.64	kg/h

Manure mixture	mg/L
TSS	20,000
TDS	20,000
TS	40,000

Temperature	15	°C
Pressure	45	kPag
Density	1,020	kg/m3
Mass flow rate	19,781.15	kg/h

Filtrate	mg/L
TSS	307
TDS	17,351
TS	17,658

Temperature	15	°C
Pressure	172.37	kPag
Density	1,000	kg/m3
Mass flow rate	11,239.68	kg/h

RO Permeate	mg/L
TSS	0.00
TDS	968.58
TS	968.58

Temperature	15	°C
Pressure	45	kPag
Density	1,000	kg/m3
Mass flow rate	1,756.60	kg/h