Separated Drinking Water From Liquid Manure for Swine

Jim Morris, Ron Fleming and Malcolm MacAlpine

Ridgetown College - University of Guelph

August 2003

Prepared for:

Ontario Pork

Project Number #03/07

Ridgetown College UNIVERSITY of GUELPH

RIDGETOWN • ONTARIO

Ontario Pork Project # 03/07 - Final Report

Title

The efficacy of separated clean water from liquid swine manure as a source of drinking water for pigs.

.

Research Establishment

Ridgetown College, University of Guelph,

Ridgetown, Ontario NOP 2CO

Telephone Number: (519)674-1545

Contact Person: Dr. Jim Morris

Personnel

Researchers:

Jim Morris

Ron Fleming

Malcolm MacAlpine

Technical Support

David Hogg, Ridgetown College, University of Guelph

Gary Brien, Ridgetown College, University of Guelph

Summer Students

Martin Van Haren - Manure Treatment

Crystal Hoddy - Swine Research Centre

Dwayne Vansickle - Swine Research Centre

Summary

The efficacy of separated clean water from liquid swine manure as a source of drinking water for pigs was evaluated in a trial at Ridgetown College, University of Guelph.

The goal of the study was to evaluate the impact of separated clean water as a source of drinking water on:

- Quality of water
- The growth performance of starter pigs
- The health status of starter pigs.

Water was recovered from liquid manure using the Vibratory Shear Enhanced Process (VSEP) unit, a membrane filtration system. The VSEP unit was fitted with a reverse osmosis (RO) filter pack. The quality of the recovered water (permeate) was assessed and water was provided as drinking water to young pigs.

A study involving the 3 water treatments (regular barn water, half barn water and VSEP permeate, and VSEP permeate) was completed. A total of 54 pigs were allocated to 9 pens of 6 pigs each. All pens were balanced for sex, with 3 barrows and 3 gilts being allocated to each pen. The data collected included initial and weekly body weights, daily feed consumption and feed consumption on a pen basis. Mortalities and their causes were recorded. Morbidity of the pigs was assessed in several ways, including their growth performance, frequency of treatment and the levels of feed consumption.

Results showed that the VSEP unit produced permeate (separated water) from liquid manure at a quality level acceptable to pigs. The data revealed that no performance or health effects resulted from providing the recovered water from liquid manure to young weaner pigs (12 - 26 kg live weight).

Benefit of Research to the Ontario Pork Industry

The ability to separate clean water and reuse it in the barn is important for water conservation considerations in livestock systems. The ability to extract water clean enough without the presence of pathogens potentially will produce a water quality good enough for drinking water to pigs. Such a capability would offer a tremendous benefit in reducing the amount of liquid spreading and to reduce the amount of water taken into swine barns.

Separated Drinking Water From Liquid Manure for Swine

Jim Morris, Ron Fleming and, Malcolm MacAlpine

Introduction

A device recently evaluated (Fleming and MacAlpine, 2003) as a liquid/solid separator for liquid swine manure appears to produce water that is clean and free of pathogens. The technology used, referred to as VSEP, is a membrane filter system, set up for reverse osmosis. It was configured in a unique manner to handle the higher solids in liquid manure. It concentrates the nutrients to a relatively high degree. VSEP (Vibratory Shear Enhanced Process) uses a vibrating membrane, resulting in a high-energy action at the surface of the membrane. This helps prevent fouling of the membrane. The resultant permeate from this filtration is a clear water product containing no pathogens and low aqueous compounds. It appears that this water could be a source of drinking water for pigs. The study was designed to explore the efficacy of the separated water from liquid manure as a source of drinking water for pigs.

Objectives

To evaluate the impact of separated clean water as a source of drinking water on:

- The quality of water recovered from liquid manure
- The growth performance of starter pigs
- The health status of starter pigs.

Procedures

A - Trials Carried Out

A study involving 3 water treatments (regular tap water, half tap water and VSEP permeate, and VSEP permeate) was conducted in the weaner pig barn of the Swine Research Centre, Ridgetown College, University of Guelph.

The water was separated from liquid manure through an apparatus containing a set of reverse osmosis membranes. The water treatments were designed using:

A) the regular tap water (municipal water source);

B) 50 % tap water and 50% separated water; and
C) separated water.

Fifty-four pigs were allocated to 9 pens of 6 pigs each. All pens were balanced for sex with 3 barrows and 3 gilts being allocated to each pen. The pigs were randomized within each sex to the pens and the water treatments were randomized to pens within each replication. The data collected included initial and weekly body weights, daily feed consumption and water consumption on a pen basis. Mortalities and their causes were recorded. Morbidity of the pigs was assessed in several ways including their growth performance, frequency of treatment and the levels of feed consumption. All data were subjected to appropriate analysis of variance procedures. The GLM procedure of SAS was used for the statistical analysis and the 0.05 level of probability used to denote significant differences between treatment means.

B - VSEP Specifications and Description

Manure was separated using a VSEP - Series LP (New Logic, Emeryville, California), setup with the RO (Reverse Osmosis) filter pack (Figure 1). The test system was supplied by Rondeau Anaerobics, Ontario. The unit was a laboratory scale model, designed for use in determining parameters for separating various test liquids. This system uses a pressure in the range 2400 to 3450 kilopascals (350 to 500 psi) and a vibrating filter pack to separate water from the manure.

The VSEP system used a vibrating stack of 18 reverse osmosis membranes, high pressure and a timed (open and closed) outlet valve to remove water from the liquid manure. The stack of membranes was vibrated through a twisting motion using an electric motor with an eccentric weight that vibrated a heavy metal plate (seismic mass), transferring the motion up a tubular tuned torsion spring to the reverse osmosis head. The vibration created a powerful shear force at the surface of the membranes that prevented fouling of the membranes with solids.


Figure 1 VSEP reverse osmosis separator

This VSEP was initially designed to process industrial products, pharmaceuticals, wastewater and water and showed promise for treating livestock manure. Presently it is in use treating digested livestock manure in Korea but has not been used on a farm scale for treating liquid manure. It is operating in a number of other applications worldwide.

The system was powered by two electric motors with a 1.1 kilowatt, 220 volt electric motor driving the vibration system and a 2.25 kilowatt, 220 volt electric motor driving a diaphragm pump to pump the influent manure and pressurize the system to up to 3450 kilopascals (500 psi). The influent manure flowed from a 50 litre tank via a 38 mm diameter plastic hose through an inline 0.297 mm (50 mesh) screen to the pressure pump. The pressurized manure was pumped through a 12.7 mm braided steel, high pressure hose to the top of the vibrating filter head. The clean water (permeate) exited the centre top of the filter head, through a clear 12.7 mm vinyl hose into a storage tank. The concentrate exited under high pressure through the bottom of the filter head via a 12.7 mm metal tube, and an automated valve that is opened and closed depending on the setting of the timer. This concentrate was then returned to the manure storage tank. The valve controlled the permeate recovery rate by the amount of time it remained closed. The longer it was closed the higher the recovery rate.

C - Separation Procedure

For optimum performance of the VSEP unit, it was necessary to pre-screen the influent manure (e.g. through a 0.15 mm (100 mesh) vibrating screen) prior to VSEP separation, in order to remove coarse solids. No vibrating screen was available for this task, so a series of three settling tanks was set up to allow separation. The influent manure, about 2-3% dry matter, was initially pumped from the storage tank into the first settling tank and allowed to settle for a minimum of 4 hours. The manure was then pumped from the top 2/3 of the first tank into the second settling tank and was allowed to settle for at least 4 hours. The manure was then pumped from the top 2/3 of the second tank using a pump with a bag filter around it, into a 0.297 mm (50 mesh) basket filter suspended in the third tank. The manure was then stored until processing when it was dipped using a pail, into the 50 litre plastic tank feeding the VSEP. The manure then passed through the in line filter to the high pressure pump and filter pack to separate the manure.

The tanks were refilled as required to keep the process going. This method of manure pre-separation was actually more effective at removing solids than using a vibrating screen, (tested earlier) since it appeared that all coarse solids, including hair were removed using this system. With an earlier study the vibrating screen allowed hair to pass through it, thus plugging the VSEP pre-filter.

The VSEP was operated to recover about 50% of the clean water from the manure. The automated valve was operated at 9/10 of a minute closed at 3450 kPa (500 psi) and 1/10 of a minute open at 2400 kPa (350 psi). This gave a permeate (clean water) flow rate of 740 mL/min to 1400 mL/min or a recovery rate of between 40% to 58%.

Manure separation to produce the drinking water for this trial was started June 11, 2003 and completed on July 21, 2003 with a total of 4,450 litres (980 Imp gal) of water produced. The water was stored in translucent poly tanks outside of the pig barn with 1150 litres (250 Imp gal) of water to start the trial. The water was allowed to stabilize at the ambient temperature so this would not be a factor influencing the pigs' consumption of the water. The VSEP water was stored in a 1360 litre tank

(300 Imp. gal.). The mixed water, half VSEP and half tap water, was stored in a 2500 litre tank (550 Imp. gal.). The tap water was also stored in a 2500 litre tank. There was an effort to have the same volume of water in all tanks at all times. This became impractical as the rate of water use was quite variable throughout the trial.

The water was pumped from the tanks using a small jet pump pressure system (Master 230 volt, 0.5 hp Jet Convertable Jet pump - 5.3 gls.) for each water source tested. Each pump was plumbed into three water meters capable of reading to the closest litre. These were plumbed to each pen and a single water nipple (Stingy water nipple/ Standard variable-age water nipple). Water meters were read daily and the values recorded. All feed was weighed and pigs were weighed at the start of the trial (June 24, 2003) and weekly until the trial was completed July 22, 2003. Pigs were monitored for drinking habits (refusal), and their relative health and well being.

Results and Discussion

A - Overview

It was estimated that the maximum amount of drinking water would be approximately 3650 litres (810 gallons). Early in the trial, it became obvious that water consumption far exceeded those expectations. On the assumption that wasted water was the main reason for this extra water use, the water nipples were changed on July 9 (Day 15 of the trial). A different design of waterer was installed, one not as easy to play with. There was an immediate reduction in water consumed and the new nipples were used for the rest of the trial. With the heavy water use it was difficult to keep ahead of the demand. On two occasions the VSEP water supply ran out a few hours before more water could be delivered.

The VSEP water had a noticeable ammonia and sulphur odour immediately after separation. If the water was allowed to stand for two or more days before use, the odours would disappear. Unfortunately, we were not able to allow the water to stand for that period of time once the trial was started, because the pigs had wasted so much water. However, the water consumption did not change even when the water was not allowed to stand for a period of time.

The ½ VSEP and ½ tap water tank developed a green algae growth by July 4 and the VSEP water tank also developed a green algae growth by July 8. This growth did not appear to change the amount of water consumed. There were higher levels of ammonia and phosphorous in these tanks than in the "tap water" tank. It appears that these nutrients, coupled with the sunlight shining on the tank allowed for the algae growth. The tap water only tank, that was chlorinated town water, did not develop a growth of algae. All of the tanks had been sanitized with chlorine and then rinsed before the trial started to destroy any algae that may have been present in the tanks.

The quantitative analysis of this study looked at:

- the quality of the water consumed by the pigs, compared to provincial drinking water standards (for humans or for livestock) for metals, minerals and *E. coli*,
- the volume of water used from each water source,
- the feed consumed and
- the weight gained by the pigs in the study.

B - Metals and Minerals Testing of Water

The water used in the study was tested extensively for mineral and metal levels that could influence the drinking water quality and could have an impact on livestock health. The results are shown in Tables 1 and 2. The values from the VSEP water met or were lower than all drinking water standards except for ammonia-N, dissolved carbon and phosphorus. Unfortunately, it was not possible to allow the water to stand for a period of time, in order to reduce the ammonia levels. The average ammonia-N concentration in the VSEP water was 93 mg/L (guideline is 0.1 mg/L). The other levels were slightly higher than the drinking water guidelines and should not present a health risk to the pigs. The VESP and Tap water (mixed half and half) also had higher levels of ammonia and dissolved carbon. Even the tap water had slightly higher levels of ammonia than the drinking water standard. This was felt to be, at least in part, due to the tank's location near the barn and the likelihood that ammonia from the barn exhaust fans entered the tank.

The VSEP unit removed from the manure 73% of the Carbonate, 81% of the Boron, 82% of the Nitrate N and virtually 100% of all other metals and minerals tested. The VSEP water, when compared to the tap water, was not as hard, had a lower turbidity, and had lower levels of Boron, Dissolved Calcium, Dissolved Silica, Magnesium, Silver, Sodium and Thallium.. The VSEP water had levels that were higher than the tap water for Ammonia-N, Nitrate-N, Dissolved Carbon, Phosphorus, Sulphate, Calcium Carbonate, Chloride, Bicarbonate, Carbonate, Total Dissolved Solids, and Conductivity. In all cases except those mentioned above, the levels found were lower than the drinking water guidelines.

C - Bacteria Testing

Three samples from each water source and the influent manure were tested for the presence of *E.coli.* The manure from the first settling tank had an average count of 123 MPN (most probable number) per mL. The manure settling tank number 3 had an average of 92 MPN per mL. The Permeate, the permeate/tap water mix and the tap water had no *E. coli* detected. The VSEP storage tank had an average of 9 CFU per 100 mL even though the permeate had none detected. It is likely there was some contamination in the tank during the experiment. The possible sources were from the transfer tank and hose, birds, or contamination from the storage tank with its close proximity to the barn.

Table 1: Water Quality Test Values - General

Metal and Mineral Tested	Units	* LDL	Base Value Guideline	Average MAN1	Average MAN3	Average PERM	Trt A Average TAP	Trt B Average VSTAP	Trt C Average VSEP
pH value	pH units	0.1	NA	**7.92**	**8.05**	**8.65**	**8.47**	**8.74**	**8.60**
Ammonia as N	mg/L	0.05	0.1	**1461.67**	**947.67**	**98.07**	**0.13**	**71.70**	**93.27**
Nitrate as N	mg/L	0.1	10	**0.68**	**0.50**	**0.12**	**0.00**	**0.00**	**0.00**
Nitrite as N	mg/L	0.02	1	**0.52**	**0.71**	**0.00**	**0.00**	**0.00**	**0.00**
Nitrate + Nitrite as N	mg/L	0.1	10	**1.2**	**1.21**	**0.12**	**0.00**	**0.00**	**0.00**
Carbon, Diss. Org. as C	mg/L	0.5	1	**564.9**	**539.17**	**2.53**	**1.27**	**2.17**	**1.67**
Phosphorus, Diss. Orth as P	mg/L	0.01	0.2	**79.93**	**79.33**	**0.26**	**0.00**	**0.00**	**0.09**
Conductivity	uS/cm	1	NA	**8993.33**	**8770.00**	**836.00**	**371.33**	**496.00**	**820.67**
Sulphate as SO4	mg/L	205	1000000	**384.33**	**360.33**	**14.33**	**3.00**	**27.67**	**34.67**
Alkalinity Ca CO3	mg/L	1	500	**7406.67**	**6506.67**	**388.67**	**159.33**	**198.00**	**341.67**
Chloride as Cl	mg/L	5	NA	**671.67**	**650.00**	**39.00**	**25.00**	**21.67**	**23.00**
Colour	TCU		NA	**12266.67**	**11533.33**	**0.00**	**0.00**	**12.67**	**10.00**
Calculated Hardness Ca CO3	mg/L	0.1	NA	**331.00**	**263.00**	**0.40**	**38.80**	**16.83**	**1.17**
Turbidity	NTU		NA	**629.00**	**132.00**	**0.15**	**1.06**	**2.50**	**2.48**
Bicarbonate as HCO3	mg/L		500	**7350.00**	**6440.00**	**372.67**	**154.67**	**187.67**	**329.00**
Carbonate CaCO3	mg/L		NA	**58.33**	**67.67**	**16.00**	**4.33**	**9.67**	**12.33**
Total Cation	meg/L		NA	**164.40**	**125.37**	**8.77**	**4.04**	**7.84**	**8.45**
Total Anions	meg/L		NA	**175.07**	**155.97**	**9.18**	**3.96**	**5.15**	**8.20**
Ion Balance	% diff		NA	**11.12**	**11.29**	**2.26**	**1.18**	**15.67**	**1.43**
Calculated T.D.S.	mg/L		NA	**9517.33**	**8147.00**	**475.67**	**223.67**	**336.00**	**445.67**
Calculated Conductivity	µS/cm		NA	**15046.67**	**11106.67**	**543.00**	**388.33**	**403.00**	**496.00**
Saturation ph @4C	pH units		NA	**6.22**	**6.32**	**9.30**	**8.69**	**8.99**	**9.35**
Saturation ph @20C	pH units		NA	**5.82**	**5.92**	**8.90**	**8.29**	**8.59**	**8.95**
Lanelier Index @4C			NA	**1.70**	**1.73**	**-0.65**	**-0.22**	**-0.25**	**-0.75**
Lanelier Index @20C			NA	**2.10**	**2.13**	**-0.25**	**0.18**	**0.15**	**-0.35**

* LDL- Lower Detection Limit of the instruments used.

Where: **MAN1** = Manure from the first settling tank; **MAN3** = Manure from the third settling tank; **PERM** = Permeate, clean water from the VSEP; **TAP** = water taken from the TAP water tank used in the trial (A); **VSTAP** = water taken from the ½ VSEP and ½ Tap water tank used in the trial (B); and **VSEP** = water taken from the VSEP storage tank used in the trial (C).

Base value Guidlines taken from Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses, SummaryTable, Livestock, CCREM (Canadian Council of Resource and Environment Ministers), 2003 and Ontario Regulation 169/03, Safe Drinking Water Act, 2002, Ontario Drinking-Water Quality Standards, Ont Min of the Env

Table 2: Water Quality Testing Values - Metals

Metal and Mineral Tested	Units	* LDL	Base Value Guideline	Average MAN1	Average MAN3	Average PERM	Trt A Average TAP	Trt B Average VSTAP	Trt C Average VSEP
Aluminum Al	mg/L	0.03	5000	**42.93**	**7.06**	**0.00**	**0.00**	**0.03**	**0.00**
Antimony Sb	mg/L	0.04	0.006	**0.63**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Arsenic As	mg/L	0.01	0.025	**0.14**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Barium Ba	mg/L	0.04	1	**1.53**	**0.00**	**0.00**	**0.11**	**0.05**	**0.00**
Beryllium Be	mg/L	0.01	100	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Bismuth Bi	mg/L	0.1	**70	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Boron B	mg/L	0.02	5	**2.79**	**1.86**	**0.52**	**0.93**	**0.74**	**0.55**
Cadmium Cd	mg/L	0.002	0.005	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Calcium, Dissolved Ca	mg/L	0.05	1000000	**108.23**	**93.43**	**0.14**	**9.38**	**3.88**	**0.41**
Chromium Cr	mg/L	0.01	0.05	**0.48**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Cobalt Co	mg/L	0.02	1000	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Copper Cu	mg/L	0.01	500	**7.62**	**1.82**	**0.00**	**0.03**	**0.03**	**0.01**
Dissolved Silica as SiO_2	mg/L	0.05	30	**127.97**	**64.10**	**1.30**	**10.09**	**5.72**	**1.49**
Iron Fe	mg/L	0.02	300	**158.47**	**21.83**	**0.00**	**0.12**	**0.09**	**0.03**
Lead Pb	mg/L	0.05	0.01	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Magnesium, Dissolved Mg	mg/L	0.02	NA	**14.82**	**7.15**	**0.04**	**3.73**	**1.74**	**0.06**
Manganese Mn	mg/L	0.02	200	**18.56**	**1.84**	**0.00**	**0.00**	**0.00**	**0.00**
Molybdenum Mo	mg/L	0.02	70	**0.58**	**0.23**	**0.00**	**0.08**	**0.04**	**0.00**
Nickel Ni	mg/L	0.05	1000	**0.61**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Phosphorus as P	mg/L	0.05	0.2	**1189.00**	**149.33**	**0.33**	**0.09**	**0.09**	**0.29**
Potassium, Dissolved K	mg/L	0.2	2000	**1543.33**	**1510.00**	**49.40**	**2.13**	**21.30**	**48.60**
Selenium Se	mg/L	0.02	0.01	**0.87**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Silver Ag	mg/L	0.01	**70	**0.00**	**0.00**	**0.01**	**0.02**	**0.01**	**0.00**
Sodium, Dissolved Na	mg/L	0.5	NA	**320.00**	**317.33**	**11.30**	**73.80**	**42.23**	**11.93**
Strontium Sr	mg/L	0.02	**5	**1.92**	**0.42**	**0.00**	**0.51**	**0.26**	**0.00**
Thallium Tl	mg/L	0.04	**2000	**0.00**	**0.00**	**0.04**	**0.08**	**0.00**	**0.04**
Tin Sn	mg/L	0.2	NA	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Titanium Ti	mg/L	0.02	NA	**2.40**	**0.50**	**0.00**	**0.00**	**0.00**	**0.00**
Uranium U	mg/L	0.5	0.02	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Vanadium V	mg/L	0.01	100	**0.43**	**0.10**	**0.00**	**0.00**	**0.00**	**0.01**
Zinc Zn	mg/L	0.01	50000	**35.70**	**7.56**	**0.00**	**0.02**	**0.01**	**0.01**

* LDL- Lower Detection Limit of the instruments used. ** becquerels per litre

Where: **MAN1** = Manure from the first settling tank; **MAN3** = Manure from the third settling tank; **PERM** = Permeate, clean water from the VSEP; **TAP** = water taken from the TAP water tank used in the trial (Treatment A); **VSTAP** = water taken from the ½ VSEP and ½ Tap water tank used in the trial (Treatment B); and **VSEP** = water taken from the

VSEP storage tank used in the trial (Treatment C)

Base value Guidlines taken from Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses, SummaryTable, Livestock, CCREM (Canadian Council of Resource and Environment Ministers), 2003 and Ontario Regulation 169/03, Safe Drinking Water Act, 2002, Ontario Drinking-Water Quality Standards, Ontario Ministry of the Environment

.

D - Water Use

Each pen of six pigs had a separate water meter to record the water used through the water nipple. The initially installed water nipples were prone to wasting of water, as the pigs played with the nipples. The tap water and the VSEP water both had some pens that were very wasteful, with up to 70 litres per day (11.7 L/pig/day) for tap water and 80 litres per day (13 L/pig/day) for VSEP water being recorded. The average use was 25 to 42 litres per day. Rates of use for the VSEP water was 3505 litres in 28 days with an average volume per pen of 42 litres per day (7 L/pig/day). For the ½ VSEP permeate, ½ tap water the total water use was 2069 litres, representing an average of 25 litres per day (4.17 L/pig/day). For the tap water, total use was 3155 litres, or 38 litres per day (6.3 L/pig/day). The pigs were weaners, weighing from 12 to 13.5 kg at the start and growing to about 26 to 27 kg when the trial was finished. It was estimated at the start of the trial that pigs this size would use around 4 to 5 litres per pig per day. This assumption was based on the results of a study by Fleming et al (1999), where pigs from 23 to 100 kg used an average of 5.54 to 7.92 litres per pig per day for drinking, washing and spray cooling.

These high values bring into question the usefulness of this data, since such a large amount of water was wasted (i.e. not consumed by the pigs). It was hoped that these numbers would reflect relative acceptance of the water but it better reflects the effectiveness of the second water nipples to limit waste.

E - Stored Water Appearance:

An interesting observation was reported on the colour of the stored water. As noted earlier, the three types of water used in the study were stored in polyethylene tanks. After a few days, algae growth occurred resulting in a green colour in the water. The amount of colour observed indicated no algae growth in the tap water (Treatment A.), the most algae growth (darker green) in the 50/50 tap and VSEP water mixture (Treatment B) and some algae growth (light green colour) in the VSEP water (Treatment C).

F - Pig Performance

Table 3 and Figure 2 show the effect of water treatment on water consumption of the pigs raised from

11 kg to 27 kg live weight. Statistically, there was no difference in water consumption (at P < 0.05) for the early period (first 10 days) and for the entire period. As mentioned, during this period the pigs seemed to waste more water in some treatments.

Table 3. Water consumption (litres/day) of pigs given the various water treatments

Period	Tap water	50%tap/50 % permeate	Permeate	SE	Probability
Early Period	5.5	3.6	6	0.806	0.17
Late Period[1]	5.0[a]	5.0[a]	6.2[b]	0.296	0.047
Overall	5.2	4.3	6.1	0.492	0.099

[1] Means across any line designated with different superscripts are significantly different at P < 0.05

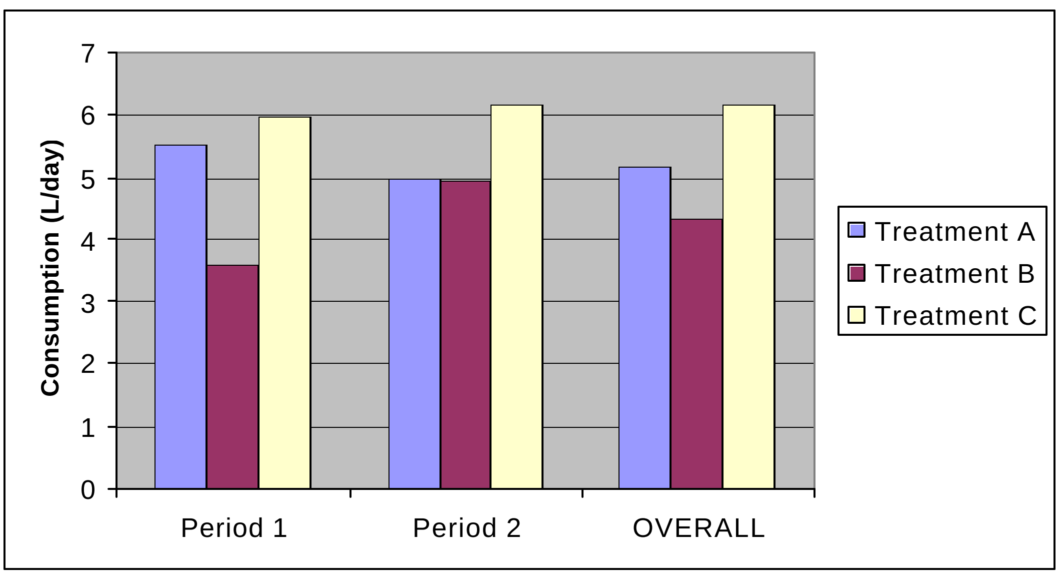

Figure 2 The effect of water treatment on pig water consumption.

During the latter period there was a significant difference in water consumption (at P< 0.05) between the permeate water (Treatment C) and the other 2 treatments (5.0, 5.0 and 6.2 litres per day for treatments A, B and C respectively). The pigs seemed to be drinking more of the permeate. The results indicate that there was no apparently deleterious effect of the separated water treatments on water consumption.

The body weight and growth performance data of the pigs watered by the experimental water treatments are shown in table 4. The body weight changes over the 28 day growth period are illustrated in Figure 3. The treatment effects on differences in growth rate and body weights were not statistically significant (Table 4, Figures 3 & 4) .

Table 4. The growth performance of the pigs subjected to the various water treatments.

Parameter	Tap water	50%tap/50 %permeate	Permeate	SE	Probability
Initial Wt. (Kg)	12.4	12.4	12.6	0.666	0.982
Week 1 Wt. (Kg)	15	14.9	15.3	0.659	0.884
Week 2 Wt. (Kg)	17.8	17.8	18.3	0.591	0.771
Week 3 Wt. (Kg)	21.8	22.1	22.7	0.64	0.65
Final Wt. (Kg)	26.6	26.9	26.9	0.64	0.913
ADFI (Kg)	1.2	1.18	1.23	0.04	0.755
ADG (Kg)	0.5	0.52	0.51	0.009	0.579
F/G	2.38	2.28	2.4	0.095	0.671

ADFI - average daily feed intake;
ADG - average daily gain;
F/G - Kg feed per Kg gain.

Average Daily feed intake was not affected by water treatment (Table 4 & Figure 4). Feed efficiency was likewise not affected by water treatment being 2.3, 2.4 and 2.4 (P = 0.671) for treatments A, B and C respectively (Table 4).

This study reveals that the reverse osmosis VSEP apparatus can clean water sufficient for livestock drinking purposes. The chemical analysis for this study as well as one previously conducted by Fleming and MacAlpine (2003) showed that the quality of permeate from the VSEP process was sufficient to provide drinking water for livestock. The present study verified that the pigs exhibited no deleterious effects from drinking the VSEP permeate.

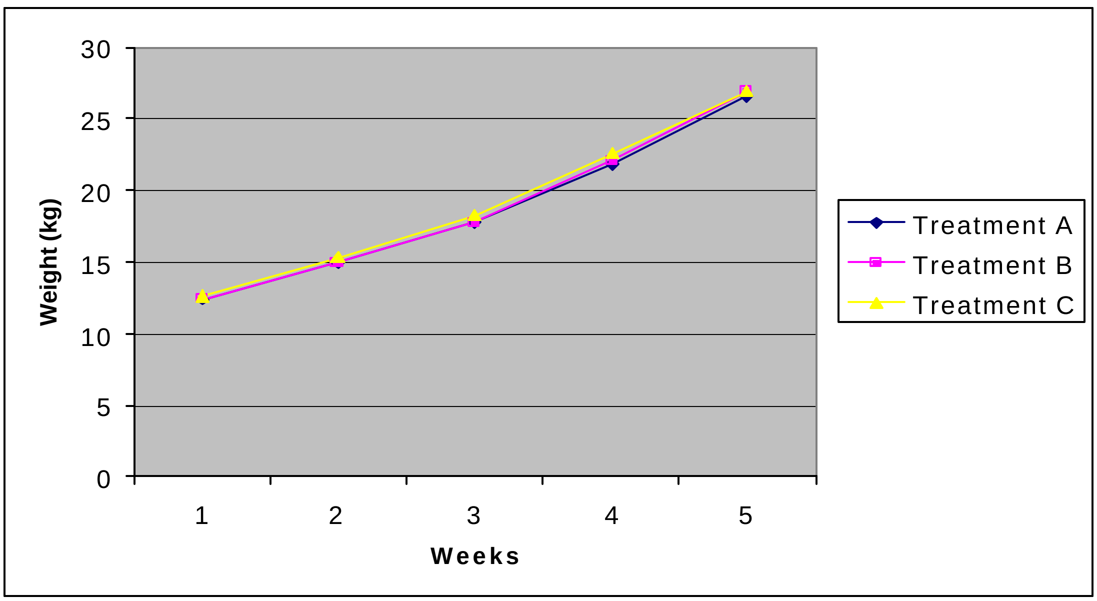

Figure 3 The effect of water treatment on body weight of the experimental pigs throughout the trial.

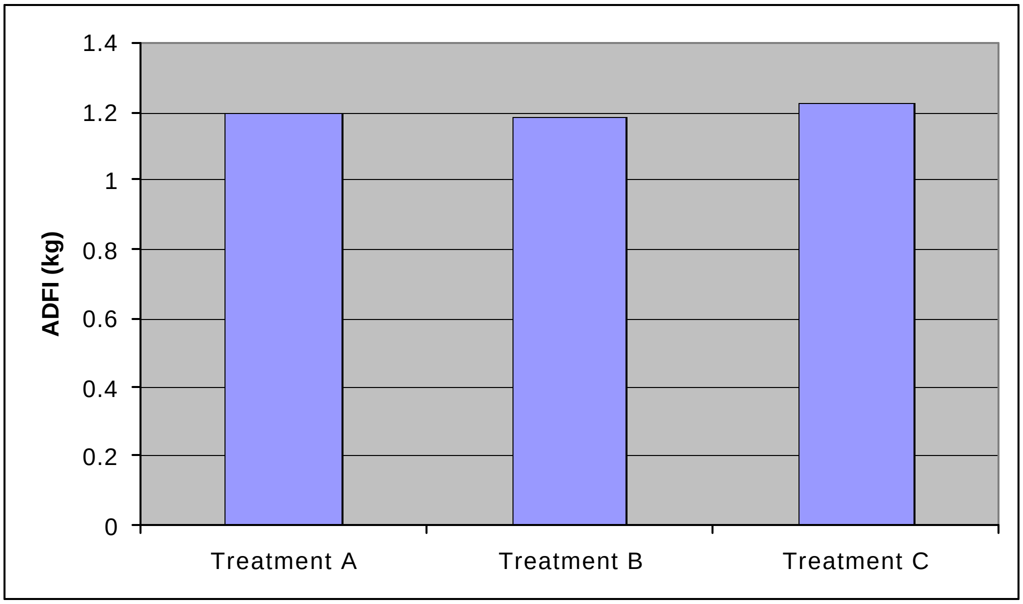

Figure 4 The effect of water treatment on average daily feed intake (ADFI) of the pigs on trial.

Conclusions

- This study showed that clear and potable water for pigs can be recovered from liquid swine manure using the VSEP (Vibratory Shear Enhanced Process) machine fitted with reverse osmosis membranes.

- There were no apparent health problems for any of the pigs on trial.

- There was no effect of water treatment on overall water consumption. There appeared to be a higher daily consumption of water per pig ($P < 0.05$) during the latter period of the study for those pigs on the separated water treatment.

- No statistical differences associated with water treatment were observed for any of the body weight measurements, average daily feed intake, average daily gain and feed conversion throughout the trial.

- The separated water (permeate) recovered from liquid manure was quite acceptable as a water source for pigs under the conditions of this experiment.

References

Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses, Summary Table, Livestock, CCREM (Canadian Council of Resource and Environment Ministers), 2003

Fleming, R., and MacAlpine, M. 2003. Evaluation of Mechanical Liquid/Solid Manure Separators. Final Report to Ontario Pork. Ridgetown College - University of Guelph

Fleming, R., Hocking, D., MacAlpine, M., and Johnston, J. 1999. Investigation of manure production in typical 3-site hog facilities. Project #97/03. Final report to Ontario Pork. June 1999

Johnson, G. 2001. Membrane filtration of hog manure - a cost-effective and environmentally sound solution. New Logic case study. New logic Research, Emeryville California.

Ontario Regulation 169/03, Safe Drinking Water Act, 2002, Ontario Drinking-Water Quality Standards, Ontario Ministry of the Environment

Acknowledgments

The authors wish to acknowledge the generous support of Ontario Pork, Rondeau Anaerobic Inc. New Logic research Inc. the Ontario Ministry of Agriculture and Food and the University of Guelph for this study.