
Can the Quality of Soil Structure be Maintained Following Repeated Applications of High Rates of Hog Manure?

T.B. Zeleke, M.C.J. Grevers, B.C. Si, and J.J. Schoenau

Department of Soil Science, University of Saskatchewan, Saskatoon, SK S7N 5A8

Key Words: swine manure, repeated application rates, soil structure, salinity and sodicity, soil zones

Abstract

The long-term impact of repeated applications of high rates of liquid hog manure on the quality of the soil and that of the environment is not well known. For optimal application rates of hog manure, improved knowledge is essential regarding the long-term effect of hog manure applications on salinity, acidity, soil density, aggregation, and soil strength. A field research project was initiated in 1998 to determine the effects of repeated application of high rates of injected swine manure (up to 13,000 g ac⁻¹) on soil quality in Southern Saskatchewan. In the fall 2001, measurements were made on different soil physical and chemical quality indicators in two of the sites with contrasting soil types: a heavy clay textured soil in the Dark Brown Soil Zone and a sandy loam to loam textured soil in the Brown Soil Zone. At the site with heavy clay textured soil, the high rates of liquid hog manure increased sodium absorption ratio (SAR), electrical conductivity (EC), and surface penetration resistance (SPR) and decreased soil pH; whereas, there were no significant changes on the quality of the surface soil at the sandy loam to loam textured soil to date other than a decrease in surface crusting index. Studies are in progress to include additional sites and also additional soil quality indicator parameters through a longer term monitoring program.

Introduction

Manure has been recognized for centuries as an organic fertilizer containing essential nutrients required for crop production. Land application of manure is a highly effective and desirable method of recycling nutrients used in crop production back to the soil. Researchers estimate that at 1998 prices, nitrogen and phosphorus production from livestock in the prairie region is valued at 323 M\$ (Larney, 1998).

When properly managed, manure not only acts as a source of plant nutrients, especially in the case of solid manure, improves soil tilth, structure, and water-holding properties through the addition of organic matter. Manure increases the aggregate stability and porosity of soils, which improve infiltration rate and aeration (Cross, et al., 1973; Swader and Stewart, 1972; Pagliali, et al., 1981). Reduction in bulk density of soils after repeated application of solid manure is also well documented (Sweeten and Mathers, 1985; Hafez, 1974; Cross et al. 1973). Manure application also reduces the strength of the soil (and surface crusting) with resultant effect of improved seedling emergence and lower surface run off (Hafez, 1974; Nuttal, 1970).

Repeated application of solid manure improves infiltration rate (Mathers and Stewart, 1981; Unger and Stewart, 1974; Hafez, 1974; Cross, et al. 1973). Mathers (1977) observed that

repeated application of high rates of cattle manure decreased surface runoff and increased water intake by about 10 to 15% as compared to the control and anhydrous ammonia treated plots. He also believed that the yield increase of manure plots over N fertilizer plots was due to increased water intake.

Application of manure in excess of plant nutrient uptake, however, may result in an accumulation of nutrients in the soil, which can adversely affect the soil quality. It is essential to know the nutrients required in the cropping program based on the existing soil nutrient levels, the crop to be grown, and the anticipated yield based on projected moisture conditions. An excess application is documented to result in ground water contamination (Chang and Entz, 1996), along with subsequent cropping problems such as lodging, poor seed germination, and uneven and delayed maturity (Weiterman, 1995; Rendell et al., 1971).

The possibility of increased salinity must also be considered. Salt accumulation and soil dispersion are two potential hazards of applying excessive amounts of animal manure to soils. Mathers (1977) found that after three consecutive years of application of 67 t/ha feedlot manure, the electrical conductivity of the saturated paste extract was increased to 7.3 dS/m, while extracts from 22 t/ha manure and inorganic fertilizer plots had a maximum conductivity of 3.1 dS/m. In the Texas Panhandle, Reddell (1974) reported two to seven times increase in sodium concentration in the top 1-foot soil from manure application rates of 600 to 900 t/ac. Yield reductions due to manure induced salinity was also reported for high rates of applications (Sweeten, 1985; Manges et al., 1971; Mathers and Stewart, 1971). The primary effects of these salts in soil are dispersion of soil aggregates and preventing water and nutrients from entering the plant (SAF, 2000).

Current hog manure application guidelines for Saskatchewan are based only on its fertilizer value. It must also be recognized that hog manure may also contain other constituents that pose potential hazard when applied in excess amounts. For example, an excess of sodium dissolved in soil solutions relative to the total electrolyte concentration can cause structural deterioration with resultant effect of surface crusting and reduced infiltration rate. Most of these changes in soil quality, however, were indicated to be a longer-term process (Azevedo, 1974 Sweeten and Mathers, 1985; Grevers, 1998) and may not be evident in one or two seasons. There is a need, therefore, to determine 'safe' application rates and threshold levels for land injection of hog manure on different Saskatchewan soils through continuous and long-term monitoring.

Objectives

To determine the long-term effect of repeated applications of liquid hog manure on the basic physical properties of the surface soil.

Methodology

A field research project was initiated in 1998 at six sites in Southern Saskatchewan to determine the effect of repeated application of hog manure on soil quality. This study looked at two of these sites – Plenty (SW5-33-18-W3) and Riverhurst (SW18-24-5-W3). The Plenty site soil is

classified as a Dark Brown Chernozem and has heavy clay texture. The Riverhurst site soil is classified as Brown Chernozem and has a very fine sandy-loam to loam texture.

The experiment has five sub-plot treatments and six main plot treatments. The sub plot treatments, which are replicated three times are: low hog manure rate ($5,500 \text{ g ac}^{-1}$), high hog manure rate ($13,500 \text{ g ac}^{-1}$), urea fertilizer at recommended N rate, urea at 2x recommended N rate, and control. The main plot treatments are manure application sequence based on number of manure application years, which range from one year to four years of applications. The hog manure is soil injected to a depth between 10 and 15 cm by pumping the manure through hoses mounted behind a sweep opener on a heavy-duty cultivator.

This study investigated the effect of the high rates of manure application for the plots which received injected swine manure for the last three consecutive years - 98/99, 99/00, and 00/01 (fall and spring applications) at $13,000 \text{ g ac}^{-1}$. The treatments selected were: high hog manure rate (HM), 2x recommended N urea (HF), and Control (C). In the fall of 2001, core and bulk samples were collected from the top 15cm soil from each plot. Infiltration rate, penetration resistance, and shear resistance were determined in-situ during the same period.

Infiltration rate was measured using double ring infiltrometers with concentric rings of 30 and 20 cm diameters and a height of 20cm. Penetration resistance was measured using a hand operated penetrometer (from Soiltest, Inc., 2205 Lee St., Evanston, IL) which has a weight of 187 g, length of 154 mm, and diameter of 19 mm. Penetration readings were taken at 0, 5 and 10 cm depths using 6.4 or 25.4 mm diameter piston needles based on the resistance of the soil. Shear resistance (shear strength of the soil) was measured using torvanes of CL-602 and CL-604 vane adapters (from Soiltest, Inc., 2205 Lee St., Evanston, IL). Shear resistance readings were taken at 0, 5, and 10 cm depths.

Bulk density and moisture content of the plots were determined from core samples. From each plot, triplicate 0-5 and 0-15 cm bulk samples were collected and air-dried. Salinity, pH, and SAR were determined from a saturated paste of the 0-15 cm bulk samples, which was ground to pass a 2mm sieve. Modulus of rupture (an index of crust strength) was determined from the 0-5 cm depth, which was ground to pass a 2 mm sieve. The balance-beam technique (Richards, 1953) was used for determining the modulus of rupture.

Result and Discussion

Initial results of this study, based on the data from in situ measurements and lab analyses of soil samples for fall 2001 are summarized in Tables 1 through 4. There were no significant differences between the bulk densities of the treatments at both sites; nevertheless, it is important to note that HM plots have slightly lower bulk density values in both sites indicating a decreasing trend, possibly due to greater straw addition from enhanced crop growth from the nutrients added. Modulus of rupture, which is an index of surface crusting of a soil, is significantly lower for the HM plots than the C and F plots at the Riverhurst site. The highest Modulus of rupture (28.7 Kpa) was observed for the C plots which is 30 % higher than for the HM plots. There were no significant differences in saturated hydraulic conductivity.

Table 1. Bulk density, saturated hydraulic conductivity (Ks), and modulus of rupture (MR) in the top 0-15 cm soil depth.

Treatments	Bulk density (Mg/m ³)		MR (Kpa)	Ks (cm/hr)
	Riverhurst	Plenty	Riverhurst	Riverhurst
HM	1.24	1.06	*14.40	5.3
F	1.27	1.07	24.32	6.8
C	1.26	1.12	28.74	4.6
LSD (0.05)	NS	NS	4.40	NS

*Significantly different from the control at $p < 0.05$

NS - not significantly different

HM denotes high rate of hog manure

F denotes urea fertilization

C denotes control

Soil pH, electrical conductivity (EC), and sodium absorption ratio (SAR) in the surface 0-15 cm of the HM and F plots were significantly different from the C plots for the heavy textured Plenty soil (Table 2). Soil pH in the HM and F plots was lower than in the C plots by 3.4 and 2.6 % respectively. EC (dS/m) increased in the HM and F plots by 1.9 and 0.6 dS/m over the control respectively. SAR increased in the HM plots by about 10 % and decreased in the F plots by 19 % as compared to the C plots. There were no significant differences in these three soil properties (pH, EC, and SAR) between the treatments in the sandy-loam textured Riverhurst soil. This difference between the Plenty and Riverhurst soils could probably be explained by the difference in the texture and leaching regions, with lower rate of leaching of salts in the heavy textured Plenty soil.

Table 2. Soil pH, salinity and sodium absorption ratio in the top 0-15 cm depth.

Treatments	pH		EC (dS/m)		SAR	
	Riverhurst	Plenty	Riverhurst	Plenty	Riverhurst	Plenty
HM	6.5	*7.4	1.4	*2.5	0.80	*1.35
F	6.5	*7.5	1.4	*1.2	0.84	*0.98
C	6.7	7.7	1.1	0.6	0.78	1.21
LSD (0.05)	NS	0.08	NS	0.5	NS	0.11

*Significantly different from the control at $p < 0.05$

NS - not significantly different

Penetration resistance of the surface soil was significantly increased for the HM plots of the Plenty site (Table 3). There were no significant differences in the surface soil penetration

resistance between the treatments in the Riverhurst site. High variability in the data for penetration resistance at the 5 and 10 cm depths masked any differences in between the treatments for both sites.

Table 3. Penetration resistances at the surface, 5 cm and 10 cm depths (in kPa).

Treatments	Surface		5 cm depth		10 cm depth	
	Riverhurst	Plenty	Riverhurst	Plenty	Riverhurst	Plenty
HM	9.6	*12.3	133.8	235.4	274.6	409.2
F	6.5	8.6	151.7	335.1	331.2	454.4
C	11.6	6.5	161.7	364.5	323.6	442.4
LSD (0.05)	NS	5.0	NS	NS	NS	NS

*Significantly different from the control at $p < 0.05$

NS - not significantly different

Table 4. Shear resistances at the surface, 5 cm and 10 cm depths (in kPa)

Treatments	Surface		5 cm depth		10 cm depth	
	Riverhurst	Plenty	Riverhurst	Plenty	Riverhurst	Plenty
HM	4.0	1.6	12.6	25.2	20.4	78.2
F	*2.9	*2.7	9.2	51.8	23.6	87.8
C	4.1	1.8	9.2	65.3	23.1	74.4
LSD (0.05)	0.44	1.03	NS	NS	NS	NS

*Significantly different from the control at $p < 0.05$

NS - not significantly different

Conclusions

Repeated application of high rates of hog manure for three consecutive years decreased soil pH and increased electrical conductivity (EC), sodium absorption ratios (SAR), and penetration resistance at the clay textured Plenty site. At the Riverhurst site, with the sandy loam textured soil, the high rates of hog manure applied did not show any significant changes in the quality of the soil except for decreasing surface crusting. Significant changes in other physical properties of the soils such as bulk density, and hydraulic conductivity were not apparent at this point in time

due to the relatively short time span of hog manure application and the high spatial variability involved with these properties. Nevertheless, the results of this study indicated a trend towards increased risk of salinity and sodicity problems in soils with low leaching region with repeated applications of high rates of hog manure.

Acknowledgements

Financial support for the research from Agricultural Development Fund and SaskPork is gratefully acknowledged.

References

- Azevedo, J., and P.R. Stout. 1974. Farm animal manures: An overview of their role in the agricultural environment. Manual 44. Calif. Agr. Exp. Sta., and Ext. Serv., Univ. Calif., Davis.
- Chang, C. and T. Entz. 1996. Nitrate Leaching Losses Under Repeated Cattle Feedlot Manure Applications In Southern Alberta. *J. Environ. Qual.* 25: 145-153.
- Cross, O.E., and P.E. Fischbach. 1973. Water intake rates on silt loam soil with various manure application. *Trans., ASAE.* 16: 282-284.
- Grevers, M.C.J. and J.J. Schoenau. 2001. Hog Manure – a Dilute Fertilizer With Extra's Pages 452 to 456. In *Soils and Crops 2001*. University of Saskatchewan, Saskatoon, SK, Canada.
- Hafez, A.A.R. 1974. Comparative changes in soil physical properties induced by admixtures of manures from various domestic animals. *Soil Sci.* 118: 53 – 59.
- Larney, Frank. 1998. *The New Manure Management*. Agriculture and Agri-Food Canada. Lethbridge Research Station. Lethbridge, Alberta.
- Mathers, A.C., and B. A. Stewart. 1981. The effect of feedlot manure on soil physical and chemical properties. In *Livestock waste: A renewable resource*. Am Soc Agr. Eng., St. Joseph, Mich.
- Mathers, A.C., and B.A. Stewart. 1971. Crop production and soil analysis as affected by applications of cattle feedlot wastes. In: *Livestock waste management and pollution abatement*. Am Soc Agr. Eng., St. Joseph, Mich.
- Manges, H.L., L.A. Schmid, and L.S. Murphy. 1971. Land disposal of cattle feedlot wastes. In: *Livestock waste management and pollution abatement*. Am. Soc Agr. Eng., St. Joseph, Mich.
- Nuttall, W.F. 1970. Effect of organic amendments on soil physical properties of Luvisolic soils in relation to emergence of rapeseed in a growth chamber. *Can. J. Soil Sci.* 50: 397-402.
- Pagliali, M., G. Guidi, M. La Marca, and G. Lucamante. 1981. Effects of sewage sludges and composting on soil porosity and aggregation. *J. Environ. Quality* 10: 556-561.
- Reddell, D.L., R.C. Egg, V. L. Smith. 1974. Chemical changes in soils used for beef manure disposal. Paper No. 74-4060. Am Soc Agr. Eng., St. Joseph, Mich.

- Reddell, D.L., W.H. Johnson, P.J. Lyerly, and P Hobgood. 1971. Disposal of beef manure by deep plowing. In Livestock waste management and pollution abatement. Am. Soc. Agr. Eng., St. Joseph, Mich. 235-238.
- Saskatchewan Agriculture and Food (SAF). 2000. Managing Manure as a Fertilizer for Prairie Agriculture
- Sweeten, J.M. and A. C. Mathers. 1985. Improving Soils with Livestock manure. J. Soil Water onserv. 40:206-210.
- Swader, F.N. and B.A. Stewart. 1972. The effect of feedlot wastes on water relations of Pullman clay loam. Paper No.72 – 959. Am. Soc Agr. Eng., St. Joseph, Mich.
- Unger, P.W., and B.A. Stewart. 1974. Feedlot waste effects on soil conditions and water evaporation. Soil Sci. Soc. Am. Proc. 38: 954-957.
- Weiterman, G.1995. Intensive Hog Operation Waste Management through irrigation. Pages 150 to 152. In Soils and Crops 1995. University of Saskatchewan, Saskatoon, SK, Canada.