Paper No. 934025

AN ASAE/CSAE MEETING PRESENTATION

ON-FARM MEASUREMENT OF AVAILABLE MANURE-N

by

R. J. Fleming, P.Eng.
Research Engineer
Agricultural Engineering Section
Centralia College
Huron Park, Ontario
N0M 1Y0

J. E. McLellan, P.Eng.
Research Engineer
Agricultural Engineering Section
Centralia College
Huron Park, Ontario
N0M 1Y0

S. H. Bradshaw
Research Technician
Agricultural Engineering Section
Centralia College
Huron Park, Ontario
N0M 1Y0

Written for presentation at the
1993 International Summer Meeting
sponsored by
THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
THE CANADIAN SOCIETY OF AGRICULTURAL ENGINEERING

Spokane Center
Spokane, Washington
20-23 June 1993

SUMMARY:

Two on-farm manure test procedures were evaluated to determine their accuracy in predicting the concentration of NH_4-N in liquid manure. One hundred and six manure samples from swine, beef, dairy, and poultry farms were evaluated. Both the nitrogen meter and the electrical conductivity method yielded reasonably accurate results. The estimates were far superior to those obtained using standard tables.

KEYWORDS:

nutrients, ammonia

American Society of Agricultural Engineers
2950 Niles Road, St. Joseph, Michigan 49085-9659 USA
Voice: 616.429.0300 FAX: 616.429.3852

CSAE SCGR

ON-FARM MEASUREMENT OF AVAILABLE MANURE-N

by: R. J. Fleming, P.Eng., J. E. McLellan, P.Eng., and S. H. Bradshaw
Centralia College, Ontario Ministry of Agriculture and Food

BACKGROUND

In the quest for more sustainable farming practices, farmers are improving the efficiency of nutrient use in their cropping programs. This "nutrient management" approach involves applying nutrients to cropland based on the expected needs of the crop to be grown. It also takes into account the reserves of nutrients in the soil. Inorganic fertilizer is considered to be a nutrient source, but credit is also given to nutrients from previous crops and from livestock manure.

Farmers are being encouraged to base manure application rates on the crop fertility needs, soil test results, and on manure test results. While many farmers send manure samples to labs for analysis, other farmers find this to be inconvenient. The real or perceived drawbacks include: a) the inconvenience of delivering a sample to the lab, b) the cost of lab analysis (approximately $25/sample for a basic package), c) the time delay involved, and d) the difficulty in getting a representative sample of manure. Usually samples are taken at spreading time because it is easiest then to get a well mixed, representative sample. However, the farmer often wants to know the nutrient application rate at spreading time instead of having to wait 2 or 3 weeks to receive results from a lab.

In the absence of lab test results, the farmer can refer to tables which give average nutrient concentrations for various types of manure. The publication Field Crop Recommendations, OMAF (1990) contains recommendations on reductions in fertilizer application rates when manure is applied in the same crop year. This publication acknowledges that the nutrient content of manure varies with the type of livestock, the age, the ration fed, the type of bedding or amount of water used, and the method of storing the manure.

The ammonium form of nitrogen (NH_4-N) is the form of N that is considered to be most available to crops in the year of application. This volatile nutrient can easily be lost from the barn and the manure storage. Other nutrients of interest include: total nitrogen, phosphorus, and potassium.

Various studies have looked at the possibility of using relatively inexpensive test kits to help measure concentrations of manure nutrients. Chescheir et al (1985) evaluated the performance of four such test kits including: a) correlation of nutrients with specific gravity (measured with a soil hydrometer), b) ammonia electrode and meter, c) water analysis field kit for ammonia, and d) a "Nitrogen Meter" that measures nitrogen gas pressure in a reaction chamber. They tested various samples of dairy and swine manure. The hydrometer method was very good for determining the total solids content of liquid manure. The ammonia electrode was very good for determining the NH_3-N concentration. The water analysis field kit for NH_3-N was adequate for swine manure but inconsistent for dairy. The nitrogen meter performed fairly well for NH_3-N.

Specific conductance (electrical conductivity) has been used to predict concentrations of N, P, and K in liquid manure. Payne (1984) measured electrical conductivity in poultry, dairy, and swine manures and found this to be a good method of predicting nitrogen concentrations in lagoons. Fleming and Bradshaw (1992) found that the nitrogen meter was fairly accurate for swine and cattle liquid manure. The conductivity pen appeared to have potential, especially for estimating NH_4-N concentration in cattle manure. The ammonia-N water test kit and the ammonia electrode method did not perform satisfactorily. The hydrometer proved to be useful in estimating the phosphorus concentration of cattle manure.

As a result of this latter study, a follow-up project was initiated to run a more thorough test of the nitrogen meter and the conductivity pen.

OBJECTIVE

To further evaluate the usefulness of the nitrogen test kit and measurements of electrical conductivity to estimate NH_4-N concentrations in liquid manure.

PROCEDURE

Samples of liquid manure were obtained from swine, beef, dairy, and poultry farms during the summer of 1992. The total number of manure samples was 106. These were composite samples consisting of manure extracted from different levels of each liquid storage. Sample bottles were refrigerated until the time of analysis. A portion of the manure was sent to the Analytical Services Lab, University of Guelph, for analysis. This provided the benchmark against which the other methods were compared. Measurements at Guelph and at Centralia College were made at about the same time. The elapsed time from sampling to analysis was less than 2 weeks.

Following is a description of the tests performed:

1. *Nitrogen Meter* The nitrogen meter is produced in Sweden (AGROS, Ovagen 1, S-533 03 Kallby, Sweden). The device consists of a stainless steel chamber with a pressure gauge. Manure is mixed with an oxidizing agent to oxidize the ammonia to nitrogen gas. The pressure gauge measures the increased pressure due to the formation of the gas and is calibrated to give the amount of nitrogen available per unit volume of manure.

Manure and dilution water were added to the meter chamber using the filler cups provided. The reagent was measured into the tipping tray in the chamber using the special scoop provided. The pressure gauge lid was fitted into place and clamped shut. This formed an air tight seal. The reagent was then mixed into the manure using a lever on the outside of the chamber. This mixing continued until the needle on the pressure gauge no longer moved higher.

2. *Conductivity Meter/Pen* The conductivity meter or conductivity pen is a convenient method of measuring electrical conductivity in liquids. Two types of measurements were taken. One was taken with a bench top conductivity meter (YSI Model 35 Conductivity Meter). The more appropriate instrument for on-farm use is the conductivity pen. This instrument is much smaller and is less expensive than the bench top model. Because of perceived inaccuracies in using this lower priced instrument, two pens were evaluated. The conductivity pens were the Cole Parmer conductivity pens (range 100/19900µS) from Cole Parmer, Chicago, Illinois. The results were compared with the bench top model results.

   The initial step was to calibrate the pen or the electrode using a calibration solution. To take individual manure sample readings, the pen was simply inserted into the manure. It was used to gently stir the manure. After up to 10 seconds a stable reading appeared and was recorded.

3. *Standard Laboratory Analysis* Following sample preparation, nutrient concentrations were determined using standard laboratory procedures. NH_4-N was measured using a colorimetric procedure on a Traax-800 machine following digestion. To measure total N, the sample was digested and a colorimetric reading was made using a Technicon Autoanalyzer. Total P was measured in the same way. Total K was measured following digestion using an atomic absorbtion spectrophotometer.

RESULTS AND DISCUSSION

Standard Laboratory Analysis The results of manure analysis for the 106 samples are listed in Table 1. This table gives the mean values, the standard deviations, and the range of results for the various parameters measured. It is clear that for most of the parameters and most of the animal types a wide range of values exists. This points out the hazards of using tables of average values to estimate the nutrient content of manure. For each animal type, the highest NH_4-N concentration was more than 10 times greater than the lowest concentration.

To further characterize the manure samples, selected ratios were calculated. These are presented in Table 2. Often in the literature, poultry manure is considered to have a higher percentage of total N in the NH_4-N form. For the samples in this study, however, swine, beef, and poultry all had 77% of the nitrogen in NH_4 form. The ratios of NH_4-N to Total P and NH_4-N to Dry Matter were calculated to determine if there was any potential to use these values for estimating nutrient contents. It appears that, in the absence of other information, the concentration of NH_4 or Total P could be estimated with some degree of accuracy with only one of the values known.

Table 1: Summary statistics for liquid manure samples.

		NH_4-N (mg/kg)	Total N (%)	Total P (%)	Total K (%)	Dry Matter (%)	Number
Swine	mean	2850	0.396	0.153	0.173	4.13	33
	S.D.	1049	0.19	0.11	0.08	2.87	
	min.	379	0.03	0.02	0.05	0.89	
	max.	4887	1.15	0.46	0.43	14.86	
Beef	mean	2088	0.279	0.110	0.168	5.50	11
	S.D.	1493	0.15	0.15	0.11	3.80	
	min.	242	0.02	0.01	0.05	0.45	
	max.	4544	0.51	0.54	0.41	12.73	
Dairy	mean	1468	0.246	0.061	0.250	4.97	30
	S.D.	1255	0.15	0.04	0.15	3.39	
	min.	189	0.03	0.01	0.03	0.63	
	max.	7168	0.76	0.21	0.64	14.79	
Poultry	mean	5930	0.790	0.311	0.308	12.09	32
	S.D.	2689	.35	0.20	0.13	9.17	
	min.	107	0.15	0	0.01	0.45	
	max.	10515	1.75	0.97	0.61	49.21	

Table 2: Averages and standard deviations of selected ratios for the manure samples.

	NH_4-N : Total N		NH_4-N : Total P		NH_4-N : DM	
Swine - mean (S.D.)	0.77	(0.16)	2.46	(1.23)	0.09	(0.04)
Beef - mean (S.D.)	0.77	(0.24)	2.64	(1.00)	0.04	(0.02)
Dairy - mean (S.D.)	0.60	(0.18)	2.51	(1.08)	0.03	(0.01)
Poultry - mean (S.D.)	0.77	(0.23)	2.50	(1.42)	0.07	(0.05)

Nitrogen Meter The nitrogen meter kit contained all the apparatus needed to perform the nitrogen test plus a hydrometer (the hydrometer is intended to be used to estimate the phosphorus concentration of the manure). The instructions were quite clear and the procedure for testing was fairly simple. The time to perform one test ranged from 3 to 6 minutes. Most of the samples were diluted at a rate of 1:1 with tap water as per the manufacturer's instructions. In a few cases, this did not yield a reading and the test was redone with two parts of manure and no water. The reading was then simply divided by 2.

The AGROS meter gives a direct read-out of kilograms of available nitrogen (NH_4-N) per cubic meter of manure. Figure 1 shows the actual NH_4-N readings plotted against the nitrogen meter readings. If the meter were 100% accurate, all of the points would lie on a line Y = X. Obviously, this is not the case. The best fit line is shown in Figure 1. Two data points were omitted in the calculation of this line. One point represented an

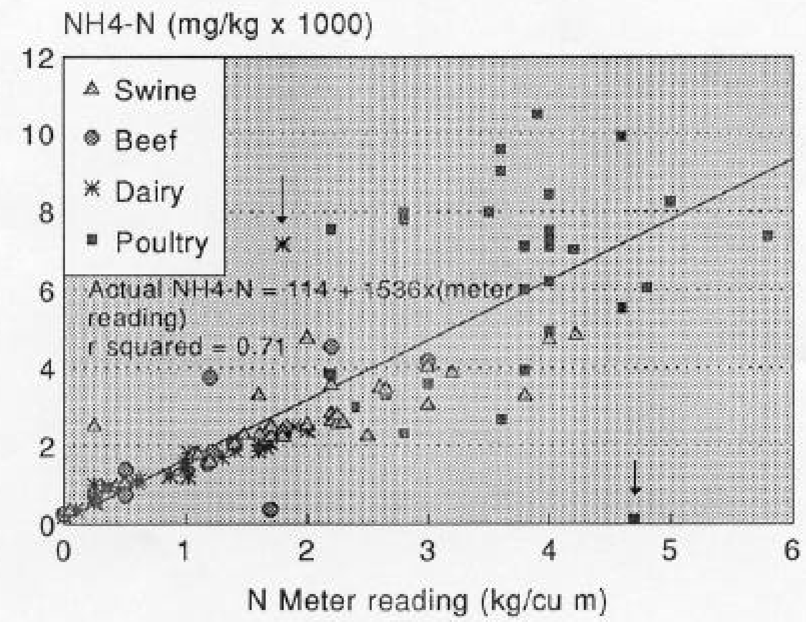

Figure 1 Actual NH_4-N vs readings from the Nitrogen Meter for all manure samples, showing best fit line and 2 outlier points deleted from analysis

abnormally high NH_4-N concentration for dairy manure and the other was an abnormally low concentration for poultry manure. Table 3 gives the results of linear regression analysis for all of the manure samples together plus for each individual animal type. The poorest fit was for poultry manure (r^2 = 0.19 initially, 0.33 adjusted). There was reasonable fit for the other animal types, especially for dairy after the removal of the one outlier value ($r^2 = 0.95$). This new line for dairy manure is shown in Figure 2.

Table 3: Linear regression of NH_4-N concentration on nitrogen meter reading.
[Actual NH_4-N (mg/L) = a + b x (Nitrogen meter reading)]

	a	b	r^2	d.f.
Overall	296	1436	0.62	104
Overall-2*	114	1536	0.71	102
Swine	1084	836	0.65	31
Beef	363	1291	0.53	10
Dairy	210	1429	0.51	29
Dairy-2**	391	1029	0.95	28
Poultry	2079	1092	0.19	31
Poultry-2**	1438	1341	0.33	30
Swine, beef, dairy	578	1072	0.63	71

* two outlier values removed
** one outlier value removed

The nitrogen meter appears to be accurate in estimating the available nitrogen content of dairy manure and to a lesser extent swine and beef manure. The meter reading must be adjusted to give a better indication of the NH_4 value. Ideally, the meter should be recalibrated so that the farmer can still take advantage of the convenience of reading the available nitrogen content directly from the dial. Alternatively, the meter reading could be modified using calibration charts specific to the different animal types. This introduces one additional step to the procedure.

Safety is a concern with this test kit. The oxidizing material is calcium hypochlorite. The test kit that was evaluated was purchased in 1991. On the reagent bottle was a sticker warning of the hazards of the material. No material safety data sheet (MSDS) was shipped with the material however.

The nitrogen meter was used in this study only for liquid samples. However, the manufacturer claims that the test kit can be also used for solid manure samples. A procedure for making these measurements is contained with the kit.

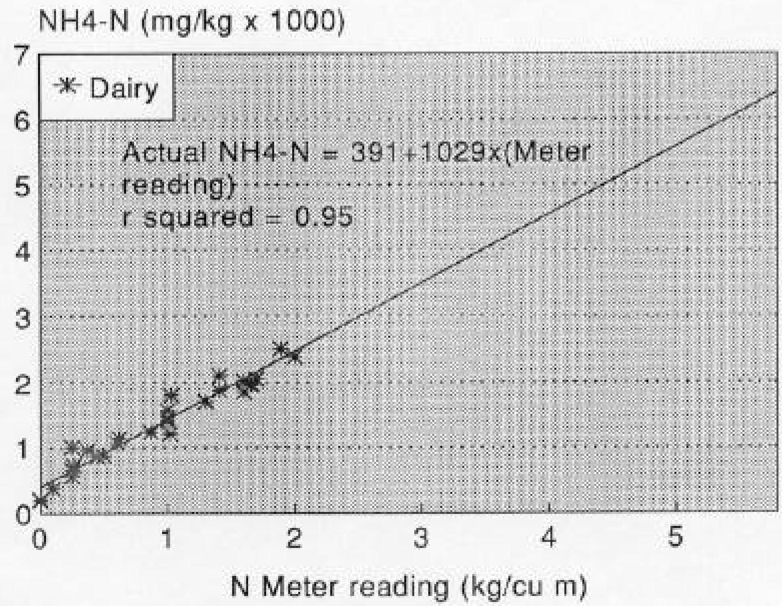

Figure 2 Actual NH_4-N vs Nitrogen Meter readings for dairy manure showing best fit line (one outlier point excluded)

Conductivity Meter/Pen The conductivity pens were ordered more than one month prior to the study period. Unfortunately, they had not arrived when the study was being carried out, and in fact did not arrive until approximately two months later. No other suppliers were found who could deliver a similar low cost conductivity pen. During the study, the manure samples were analyzed using the bench top conductivity meter.

Almost one half of the samples were then refrigerated until the conductivity pens arrived. At that time, the samples were re-analyzed with the bench top meter and the conductivity pens. The purpose of this measurement was to determine: a) if the conductivity reading changed over the period of 1 1/2 to 2 months, b) if the conductivity pens gave similar readings to the conductivity meter, c) if the two conductivity pens gave the same readings. The conductivity readings and NH_4-N concentrations are plotted in Figure 3. This shows the values for the various livestock types. An overall best fit line is drawn on the graph (r^2 = 0.83).

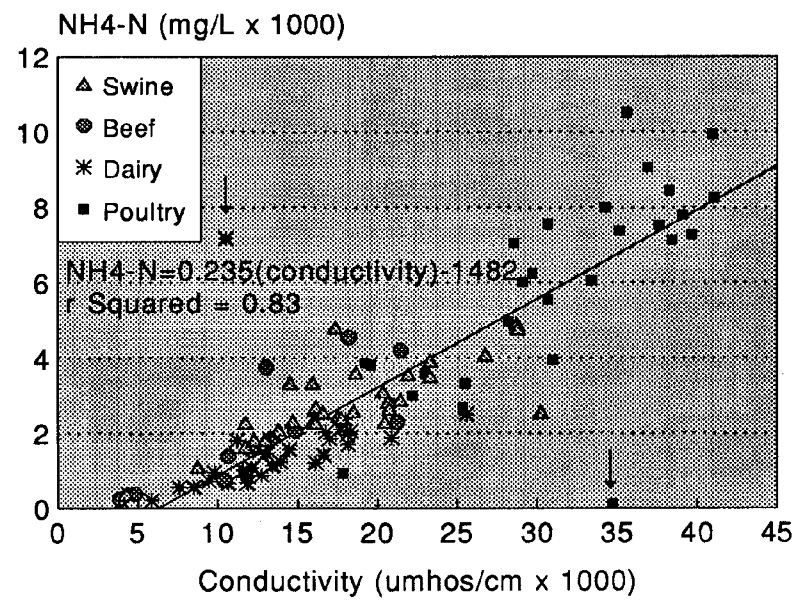

Figure 3 Actual NH_4-N vs electrical conductivity for all manure samples, showing best fit line (2 outliers were deleted from analysis)

Results of the linear regression analysis for the various animals types are shown in Table 4. As was the case with the nitrogen meter, removal of the 2 outlier values improved the fit of the lines affected. The information for dairy manure is plotted in Figure 4.

The results for the follow-up test were slightly different from the original results. While the values were not exactly equal, a linear relationship still existed between the conductivity readings from the two test dates (which were over one month apart). The r^2 value for this line was 0.95. Likewise, a linear relationship existed between the results for the bench top meter and the two conductivity pens at the follow-up testing date (r^2 = 0.94 for one of the pens and r^2 = 0.95 for the other). The results for the two pens were almost identical (r^2 = 0.99). All of this follow-up testing suggests that the two conductivity pens are just as useful as the bench top meter at estimating the NH_4-N concentration of livestock manure.

Table 4: Linear regression of NH_4-N on conductivity where [Actual NH_4-N (mg/L) = a + b x (conductivity (μmhos)]				
	a	b	r^2	d.f.
Overall	-1136	0.218	0.70	101
Overall-2*	-1482	0.235	0.83	99
Swine	403	0.132	0.57	31
Beef	-613	0.206	0.63	10
Dairy	211	0.094	0.14	29
Dairy-2**	-332	0.119	0.82	27
Poultry	-2994	0.284	0.58	28
Poultry**	-3360	0.304	0.78	27

* two outlier values removed
** one outlier value removed

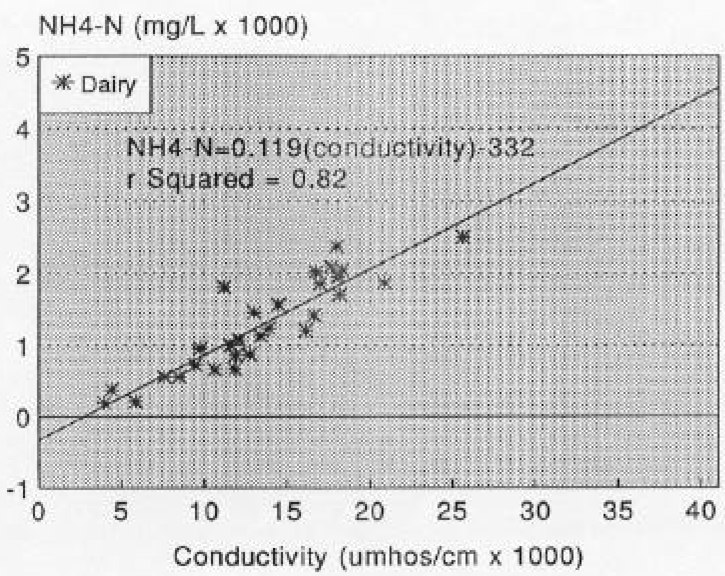

Figure 4 Actual NH_4-N vs electrical conductivity for dairy manure

A regression analysis was performed on the data from the original test to see if other relationships existed for conductivity. It appears that conductivity measurements would not be useful to estimate the dry matter concentration (r^2 = 0.11), the concentrations of total phosphorus (r^2 = 0.30) or total K (r^2 = 0.36). However, there was a linear relationship between conductivity and total N (r^2 = 0.71).

The conductivity pens were very easy to use. A reading can be made in a matter of seconds. Calibration charts would be needed to interpret this reading. One chart would be needed to perform a temperature correction (assuming the manure samples would not be at 25° C) and the other chart would simply contain the line from Figure 3 to convert conductivity reading to NH_4-N concentration. The greatest inconvenience with this system is the initial calibration of the instrument. Specially prepared calibration solution is available. Unfortunately, these solutions tend to have a limited shelf life.

Costs The cost of a conductivity pen plus a small bottle of calibration solution is less than $100 (Cdn). In contrast, the nitrogen meter cost approximately $580. Laboratory analysis is available in Ontario for a cost of approximately $30. per sample. One advantage of the test kits is that several samples can be taken from a manure storage. It is then possible to see if there is a change in NH_4 concentrations as the storage is being emptied.

Comparison of Results A comparison was made between results obtained using the two test kits and numbers obtained simply from referring to a table. In the Field Crop Recommendations Publication (OMAF, 1990), average nutrient concentrations of different types of animal manure are found. Based on the numbers in this publication, the equivalent concentrations of NH_4-N in liquid livestock manure are 1200 mg/kg for cattle, 1900 mg/kg for swine, and 5800 mg/kg for poultry.

Using the equation for the best fit line for the conductivity meter and for the nitrogen meter, estimations of NH_4-N concentrations were made for the manure samples in the study. The actual lab analysis value was subtracted from the predicted value. The magnitudes of these values were then averaged and expressed as a percentage of the actual values. This then gave a representation of the magnitude of error that could be expected using each method. This information is displayed in Figure 5. It also shows the same analysis for the table values and for the case where the best lines for each animal type were used (ie 4 equations instaed of 1).

It is obvious from Figure 5 that the least accurate method of estimating NH_4-N concentrations is using the tables. The table values were generally less than the actual NH_4 values. Based on the samples in this study, it appears that using the table will give estimates of NH_4 that will be off from the actual value by an average of about 40% to 60%. The estimates could be either higher or lower.

The average error values for the nitrogen meter are in the range 22-34%. Swine and dairy manure samples had the lower averages. These numbers were reduced to 2.1 to

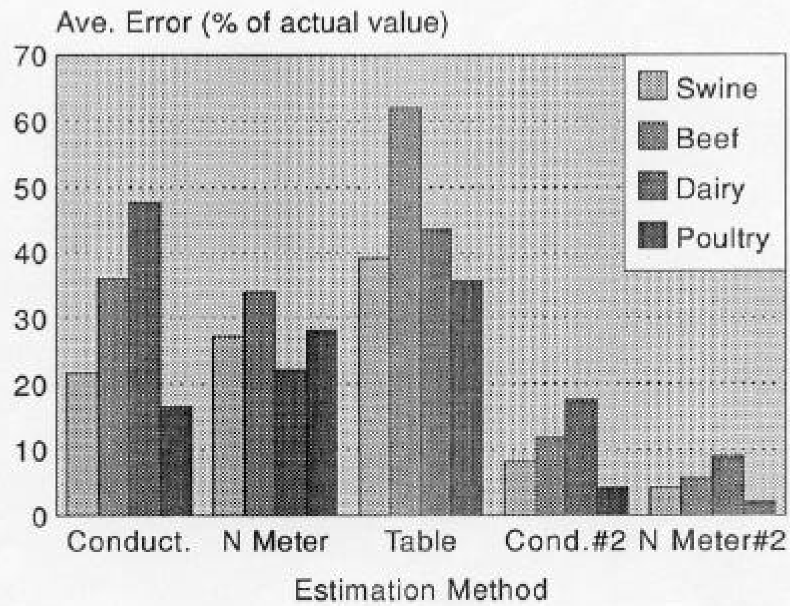

Figure 5 Magnitude of error between predicted and actual concentrations of NH_4-N using various methods: conductivity (1 equation), N Meter (1 equation), standard tables, conductivity (4 equations) and N Meter (4 equations)

9.0% when individual equations for each animal type were used. The conductivity meter error values ranged from 16.5% for poultry to 47.8% for dairy. However, when the individual equations were used, the range dropped to 4.2 to 17.5%.

Adjusting the table values to reflect the average found in the study helped to reduce the error of estimation of NH_4. The new errors ranged from 28% for swine to a high of 56% for beef.

It appears that there are alternatives to sending manure samples to a lab for chemical analysis. The table values provide no more than a crude estimate. A better estimate can be obtained from using one of the two test methods. Both the N meter and the conductivity pen can be used to give relatively accurate estimates of available N in liquid manure. When accuracy, ease of use, and cost are considered, the conductivity method rates higher than the nitrogen meter.

SUMMARY

Two methods of estimating the available nitrogen content of liquid manure were evaluated. NH_4-N concentration were estimated using a measure of electrical conductivity and using a nitrogen meter (from AGROS). A standard laboratory analysis was performed and used as the benchmark concentration. For comparison purposes, recommendations from standard tables were also used. In total, 106 liquid manure samples were tested. These represented four animal types: swine, beef, dairy, and poultry. The main findings are as follows:

1. The nitrogen meter proved to be reasonably accurate at predicting the NH_4 concentration of dairy manure (r^2 of the regression line = 0.95). To be useful to the farmers in this study, the instrument would have to be recalibrated. Alternatively, a chart could be used to adjust the readout.

2. The conductivity pens gave very similar readings to the bench top conductivity meter.

3. The relationship between conductivity and NH_4-N concentration yielded a straight line with an r^2 value of 0.83.

4. The estimation method which lead to the greatest errors was using the standard values in the tables. This is not surprising considering that the coefficients of variation for this study were 37% for swine, 72% for beef, 85% for dairy, and 45% for poultry.

REFERENCES

Chescheir, G.M., III, Westerman, P.W., Safley, L.M., Jr. 1985. Rapid methods for determining nutrients in livestock manures. Trans. of ASAE, Vol. 28(6) pp. 1817-1824.

Fleming, R.J., Bradshaw, S.H., 1992. Evaluation of on-farm manure test kits. Paper No. 92-518, CSAE, Brandon, Manitoba.

OMAF 1990. 1991-1992 Field Crop Recommendation. Publication 296, Ontario Ministry of Agriculture and Food. 91p.

Payne, V.W.E. 1984. Specific conductance of waste water as a indicator of nutrient content. Paper No. 84-4086, ASAE, St. Josephs, MI.