A FIELD DEVICE FOR SLURRY NUTRIENT CONTENT ASSESSMENT

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ABSTRACT

Agricultural slurries contain useful amounts of plant nutrients. However, the quantity of these nutrients available in a particular slurry is not easy to quantify without laboratory facilities. Thus, when these slurries are applied to land, their fertilizer potential is often unknown. This has both agronomic and environmental implications.

In order to achieve the goal of making better agronomic use of slurry and reducing pollution risks, convenient methods and means are necessary to (1) quantify the nutrients in slurry and (2) spread them efficiently and accurately in accordance with codes of good agricultural practice. For these reasons, a device for indirect measurement of nutrient content of slurry has been developed. The prototype sensor that was developed has been tested on manure samples collected from farms with different livestock typologies. A comparison between measurements obtained with the sensor and with standard laboratory analyses has been carried out.

The device is able to process the electrical signal of a probe inserted in the slurry in order to show indirectly the nutrient content of the manure. The results of tests carried out have shown the significance of the correlation between the nutrient content of slurry and its electrical properties measured by the device. Thus, the device developed seems to be a valid support for a better agronomic use of slurry by giving to farmers low cost and direct indications of nutrient content of the slurry.

INTRODUCTION

Animal manures contain useful amounts of plant nutrients (Scotford et al., 1998) that promote the use of these materials in agriculture as fertilizers. In many animal production systems, animal manure is managed as a slurry, *i.e.*, a mixture of manure and varying quantities of water or other liquid. To apply slurries in agricultural fields without knowing their nutrient composition could produce environmental and agronomic problems. Although slurries can be analyzed chemically using laboratory methods, unfortunately laboratory analyses require a long time to complete and are not usually economical.

Because of these problems, new methods to help farmers know the composition of the slurries before their distribution on the land (in agreement with the Codes of Good Agricultural Practice) are necessary. In the last decades different systems have been proposed for measuring chemical and physical features of slurries (Smith et al., 1993; Sullivan et al., 1997) and determine an estimate of the fertilizer compound they contain.

There are different methods such as *Agrosmeter* and *Quantofix*, for ammonium nitrogen (Van Kessel and Reeves III, 2000); the *hydrometer* for nitrogen and phosphorous (Zhu et al., 2004); *selective ion method for nitrogen* (Price et al., 2003); and *NIR technology* (near-infrared; Millmier et al., 2000) for nitrogen and potassium.

However these methods do not always provide immediate results because the methods use dilutions of slurry and / or need reagents. Another problem is the difficulty of obtaining a representative sample due to the heterogeneity of individual slurries. Other approaches for estimating the fertilizer content of animal manure are based on electrical conductivity (EC) measurements (Stevens et al., 1995).

MATERIAL AND METHODS

Experience with EC measurement techniques was used to develop the *Fertimeter NPK*, which is an instrument able to estimate the quantity of total Kjeldahl nitrogen (TKN), ammonium nitrogen (AN), total phosphorous (P_2O_5) and total potassium (K_2O), expressed in Kg m^{-3} contained in slurry.

Table 1*. Maximum, minimum, mean (x) and standard deviation (s) values of the studied slurries.*

Property		Cattle		Pigs		
		Calves	Dairy cows	Finisher	Farrowing sows	Complete cycle
pH	Min	6.56	6.20	6.70	5.55	6.03
	Max	7.87	7.90	8.17	8.11	9.80
	x and s	7.28 ± 0.33	7.34 ± 0.42	7.38 ± 0.32	7.46 ± 0.50	7.91 ± 0.73
Dry matter (DM)kg DM m^{-3}	Min	5.00	19.90	5.39	3.00	1.13
	Max	32.00	120.00	67.44	42.57	60.90
	x and s	12.24± 5.16	60.22± 28.66	23.12±16.35	15.02±10.51	14.5±16.13
Electrical Cond. (EC) mS cm^{-1}	Min	5.85	7.34	5.35	3.60	3.50
	Max	24.70	16.89	29.57	38.10	24.50
	x and s	17.12 ± 4.67	11.71±2.63	15.22 ± 6.08	15.46 ± 7.99	11.35±6.53
Total nitrogen (TKN) kg N m^{-3}	Min	0.78	0.94	0.85	0.45	0.20
	Max	2.73	4.11	5.40	5.62	4.32
	x and v	1.85 ± 0.43	2.50 ± 1.01	2.83 ± 1.13	2.29 ± 1.15	1.84 ± 0.96
Ammoniacal N (AN) kg N m^{-3}	Min	0.57	0.26	0.44	0.19	0.08
	Max	2.40	1.86	3.50	4.97	3.30
	x and s	1.62 ± 0.40	1.09 ± 0.57	2.00 ± 0.78	1.76 ± 0.94	1.26 ± 0.85
Percentage AN	x	87 %	44 %	71 %	77 %	68 %
Phosphorus (P) kg P_2O_5 m^{-3}	Min	0.27	0.44	0.45	0.09	0.18
	Max	1.17	2.29	4.32	9.14	1.63
	x and s	0.64 ± 0.25	1.33 ± 0.62	1.42 ± 0.97	1.37 ± 1.89	0.54 ± 0.43
Potassium (K) kg K_2O m^{-3}	Min	0.62	0.38	0.34	0.34	0.70
	Max	3.60	5.18	5.16	7.14	2.94
	x and s	2.63 ± 0.72	2.52 ± 1.28	2.28 ± 1.22	2.18 ± 1.53	1.58 ± 0.74

Fertimeter NPK

Fertimeter NPK is composed of (1) a *switchboard*, which contains the electric components and the correlation curves relating EC to fertilizer components, and (2) a *probe* formed by two electrodes. When the probe is immersed in slurry, the electrical resistance between the electrodes decreases (*i.e*., electrical conductivity increases). The switchboard is able to read this EC and translate it immediately into fertilizer content (TKN, AN, P_2O_5 and K_2O) using the pre-programmed correlation curves.

One of the advantages of this device is the possibility to have an immediate estimation of the slurry composition without another test. It is possible to use the probe manually (to do measures at different points, as in a slurry store) and directly installed in a slurry tanker (to know the amount of fertilizing elements that are being distributed in every load).

Correlation between EC and fertilizer elements

A total of 140 samples from different livestock typologies were collected (table 1) to establish correlations between the EC and the main fertilizer elements in animal slurry (TKN, AN, P_2O_5 and K_2O). All samples were homogeneously withdrawn from slurry storages on different Italian farms during the agitation process. Samples were analyzed in the laboratory for TKN, AN, P_2O_5 and K_2O using standard methods (APHA, 1998).

RESULTS AND DISCUSSION

Variability in slurry composition

The compositions of the different animal slurries are significantly variable, but are a function of the source animal (table 1). Therefore, different livestock typologies were studied individually, and different correlation coefficients (EC / TKN-AN-P_2O_5-K_2O) were calculated, as specified in the table 2.

Illustrations of the variability in slurry composition are the DM ammount and the AN content as a percentage of TKN. While AN in the three pig slurries was nearly 70% of TKN, this ratio was 44% in slurries from dairy cows and almost to 90% in slurries from calves.

On the contrary, the mean DM for dairy cow slurries was very high (60.22 kg DM m^{-3}), smaller for the three pig slurries (about 20 kg DM m^{-3}) and significantly lower in slurries from calves (12.24 kg DM m^{-3}). Besides, the large standard deviation in DM around the mean indicates how highly variable the slurries are within the same livestock typology. DM variations affect the amounts of the other elements that are contained in the slurries.

***Table 2**. Selected single correlation coefficient for nutrients according to livestock typology.*

Nutrient (kg m^{-3})		Cattle		Pigs		
		Calves	Dairy cows	Finisher	Farrowing sows	Complete cycle
	Samples	27	22	30	40	21
TKN	r^2	0.7279 **	0.8479 **	0.8010 **	0.8567 **	0.6303 **
AN	r^2	0.7950 **	0.7728 **	0.7510 **	0.8598 **	0.9354 **
P_2O_5	r^2	0.0018 n.s.	0.5617 **	0.1384 *	0.1360 *	0.2821 n.s.
K_2O	r^2	0.4092 **	0.6404 **	0.1508 *	0.7536 **	0.8352 **

*n.s. = not significant; *, ** significantly different at P = 0.05 and 0.001, respectively.*

EC and fertilizer elements

Because of the variability in slurry composition, different livestock typologies were studied individually. As seen in table 2, linear correlation coefficients (r^2) for regressions between EC and the four fertilizer elements varied as a function of livestock typology and also as a function of the parameter being correlated with EC.

Good correlations between EC / TKN were found for all animal typologies, but these were particularly high for slurries from dairy cows ($r^2 = 0.85$) and from farrowing sows ($r^2 = 0.86$). There were also very positive correlations ($r^2 = 0.8$) between EC / AN, but especially for complete cycle pig slurries ($r^2 = 0.94$).

Unfortunately, the correlations between EC / P_2O_5-K_2O were not as strong as those between TKN-AN. While for potassium correlations in slurries from farrowing sows and for complete cycle pig slurries were high ($r^2 = 0.75$ and 0.84, respectively), there was only a good correlation in slurries from dairy cows ($r^2 = 0.64$), and no significant correlation in slurries from calves and finisher pigs.

Similarly, the correlation between EC / P_2O_5 was not very significant for any of the livestock typologies studied. The highest correlation was observed in slurry from dairy cows ($r^2 = 0.57$), while for the other livestock typologies was little or no significant correlation between EC / P_2O_5. As a typology, slurry from dairy cows exhibited the best overall correlations between EC and the four fertilizer elements evaluated.

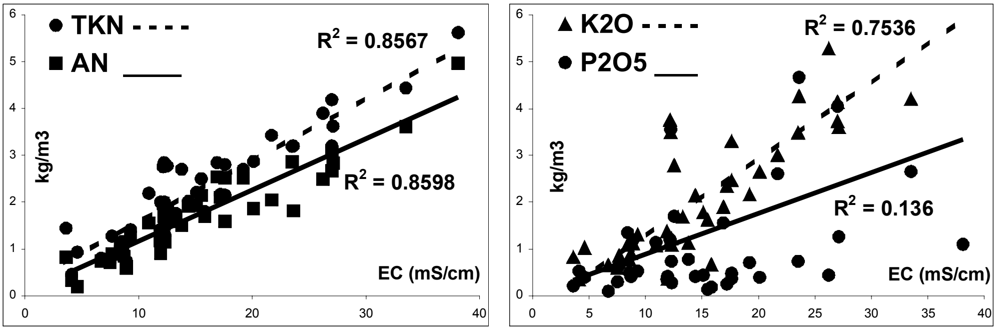

Figure 1. *Correlations between EC and TKN, AN, P_2O_5, and K_2O for farrowing sows slurries.*

CONCLUSIONS

From the correlation coefficients shown in Table 1, we can say that *Fertimeter NPK* predicts TKN-AN-K_2O in the slurry types examined with acceptable accuracy, and represents an improvement over existing methods of assessing these fertilizer elements in slurries. *Fertimeter NPK* yielded high correlations between EC / TKN-AN, and good correlation with K_2O. In the case of P_2O_5 no significant correlation was found. A possible solution to this shortcoming would be to correlate P_2O_5 with the other fertilizer elements, however this was beyond the scope of the study reported here. In addition to its ability to estimate the content of some fertilizer elements in animal slurries, the *Fertimeter* represents an easy, safe and comfortable device to use (it doesn't need technical personnel). Besides *Fertimeter* does not need to diluted samples, nor any type of reagent. Furthermore, it needs minimal maintenance.

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