THE EFFECTS OF THE SUBSTITUTION OF POLYACRYLAMIDE FOR ACTIVATED CARBON IN THE SODIUM BICARBONATE EXTRACTION OF SOILS FOR AVAILABLE INORGANIC PHOSPHORUS

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Introduction

Activated carbon has been used in the original sodium bicarbonate extraction method (Olsen et al., 1954) to help clarify extracts by removing organic material, fine clay and silt particles from suspension. If not removed, the organic material tended to increase the inorganic phosphate in solution through hydrolysis of suspended organic phosphates during colour development. Similarly, if not removed, silt and fine clay particles require the use of very fine filter paper and filtration tended to be very slow. The adoption of ascorbic acid instead of stannous chloride in the molybdenum blue method (Watanabe and Olsen, 1965) has accelerated the colour development and prevented the hydrolysis of organic phosphates thereby removing the necessity of using activated carbon in manual methods. Activated carbon has been retained in many soil testing laboratories due to its action as a flocculating agent and the subsequent ease and speed of filtration of sodium bicarbonate extracts.

Recently it has been impossible to find a suitable commercially produced carbon which is low in phosphate content. Many commercially available activated carbon products release phosphate when treated with 0.5 M $NaHCO_3$ and therefore pretreatment with 0.5 M $NaHCO_3$ solution, followed by washing with water and drying is necessary. This procedure is not only tedious but is very messy. Dispensing with carbon, completely, increases the filtering time and therefore the time of contact of the extractant with the soil, especially in heavier textured soils. Longer time of contact has been shown to increase the amount of phosphate extracted into the filtrate (Bowman et al., 1975).

The use of polyacrylamide as a flocculating agent has been proposed by Banderis et al. (1976) as a substitute for activated carbon in the sodium bicarbonate extraction. They investigated a number of decolourizing and flocculating agents and recommended polyacrylamide to reduce the colour of all mineral soils and most organic soils. They found that the use of this material helped flocculate the fine clay and silt particles allowing the use of coarser filter paper which speeded up the analytical procedures.

The object of the work reported here was to compare the effectiveness of polyacrylamide to activated carbon in the sodium bicarbonate extracts of typical Saskatchewan soils and to study the significance of using this compound on soil test results. The effectiveness of polyacrylamide as a flocculating agent was examined by:-

(1) comparing the inorganic phosphate results obtained from different sodium bicarbonate extraction of the same series of light textured soils of the Bradwell Association using activated carbon and three different concentrations of polyacrylamide,

(2) using polyacryamide and activated carbon to determine extractable inorganic phosphate on soils of the Weyburn Association containing high percentages of organic matter and sodium bicarbonate extractable organic phosphate, and

(3) comparing the results obtained by use of carbon and polyacrylamide on a randomly selected group of farm samples that had been analyzed by the Saskatchewan Soil Testing Laboratory.

Material and Methods

Polyacrylamide Solution in 0.5 M $NaHCO_3$:-

- 5 ml 0.05% aqueous polyacrylamide (B.D.H. Chemicals, molecular weight >5 x 10^6, No. 29788 - 3N) solution is added per litre of 0.5 M $NaHCO_3$, and the pH is adjusted to 8.5 with NaOH.

Determination of Extractable Phosphate:-

- the method of soil extraction was that of Olsen et al. (1954) and Watanabe and Olsen (1965). When carbon was used an equal amount was weighed into each sample and also into two blank flasks thus ensuring that no error would arise from any phosphate in the carbon. The determination of inorganic phosphate was carried out by the automated method of Hamm et al. (1970) currently used in the Saskatchewan Soil Testing Laboratory.

Results

(1) Use of activated carbon versus three polyacrylamide concentrations in the extractant

Three different levels of polyacrylamide addition were:-

(a) the suggested level of 5 ml 0.05% aqueous polyacrylamide per litre of 0.5 M $NaHCO_3$ solution (Banderis et al., 1975).

(b) 10 ml 0.05% aqueous polyacrylamide per litre of 0.05 M $NaHCO_3$ solution.

(c) 15 ml 0.05% aqueous polyacrylamide per litre of 0.05 M $NaHCO_3$ solution.

Samples from various soil depths were chosen for analysis. The results (Table 1) showed that there were no significant differences, which could not be attributed to sampling error, in the use of varying concentrations of polyacrylamide. Consequently, all further studies were done using the level of polyacrylamide suggested in the original method, namely, 5 mls 0.05% aqueous polyacrylamide per litre 0.05 M $NaHCO_3$ solution. On average the inorganic phosphate in polyacrylamide

Table 1. Comparison of inorganic phosphate extraction by sodium bicarbonate containing three polyacrylamide concentrations and activated carbon.

Depth (in.)	Analyzed Jan. 1979 P μg g^{-1} soil Poly. 1	Poly. 2	Poly. 3	Ave. μg g^{-1}	Analyzed Sept. 1978 P μg g^{-1} soil carbon	Ave. Poly. carbon %
0-6	7.3	6.9	7.3	7.2	7.3	98
0-6	9.9	10.1	9.7	9.9	8.0	124
0-6	7.1	-	7.3	7.2	6.9	104
0-6	4.1	4.1	-	4.1	4.3	95
6-12	1.9	-	1.9	1.9	1.3	146
6-12	1.9	2.5	2.5	2.3	2.4	96
6-12	2.5	3.1	-	2.8	2.5	112
12-18	0.7	0.9	1.1	0.9	0.6	150
12-18	0.9	1.3	1.1	1.1	1.1	100
12-18	-	0.7	0.9	0.8	0.8	100
Mean value				3.82	3.52	

treated extracts was 0.3 μg P/g higher than in the activated carbon treated extracts. However, this could be due to the sample variation or to small increases in extractable phosphate on storage, as there was a five month interval between analyses.

(2) Comparison of polyacrylamide versus activated carbon on sodium bicarbonate extracts of soils high in organic matter and extractable organic phosphate

The next trial involved the use of soils from the Weyburn Association of high extractable organic phosphate status (Table 2). Extractable organic phosphate ranged from 10 to 81% of the total extractable phosphate. The mean value of inorganic phosphates obtained with polyacrylamide was similar to the mean value obtained with carbon. In general slightly lower results were obtained with polyacrylamide on the soils with low organic phosphate and slightly higher results were obtained with samples of high extractable organic phosphate content. These small differences could be due to sample variation and/or small storage effects. The recovery of phosphorus added to the polyacrylamide extracts was acceptable, averaging 97%.

Banderis et al. (1976) suggest that soil extracts containing more than 20% of organic matter produce precipitates after acidification. However when the extracts were rerun on the autoanalyzer, omitting the addition of L'ascorbic acid, no response on the recorder was obtained proving that the formation of precipitates after acidification was not the cause of the slightly higher results. Possibly the high organic

Table 2. Amounts of inorganic and organic phosphate ($\mu g\ g^{-1}$ soil) extracted from cultivated and virgin soils of the Weyburn Association by sodium bicarbonate containing activated carbon or polyacrylamide.

Weyburn Association	Depth (in.)	Analyzed June 1978 0.5 M $NaHCO_3$ extract: With carbon Inorganic P	Analyzed June 1978 0.5 M $NaHCO_3$ extract: Without carbon Organic P	Analyzed June 1978 0.5 M $NaHCO_3$ extract: % organic P	Analyzed Jan. 1979 0.5 M $NaHCO_3$ ext. with polyacrylamide inorganic P*	Polyacrylamide / carbon %	Percentage recovery of polyacrylamide extract**
Cultivated	0-3	16.95	1.80	10	13.13 ± 1.03	77	101
Cultivated	0-3	25.50	8.40	25	21.60 ± 1.44	85	104
Fallow	0-3	8.70	3.05	26	7.27 ± 0.31	84	97
Virgin	0-3	6.75	17.75	72	8.60 ± 1.11	127	93
Virgin	0-3	6.45	14.30	69	8.87 ± 0.58	138	96
Virgin	0-3	7.65	21.10	73	8.27 ± 0.46	108	94
Virgin	0-3	7.75	14.25	65	8.40 ± 0.53	108	92
Virgin	0-3	7.10	17.40	81	6.93 ± 1.14	98	96
Virgin	0-3	7.35	21.65	77	9.93 ± 0.76	135	100
Mean value		10.47			10.33		

*Average of 3 replicates
**P added equal to 1 $\mu g\ ml^{-1}$ extract

phosphate content in these particular extracts were partially hydrolyzed by the addition of the acidic molybdate solution. Two extracts were further tested by a standard addition curve method, the back plots of which gave 21.6 and 9.0 μg P/g by the polyacrylamide method.

(3) Comparison of polyacrylamide versus carbon in randomly selected soil test samples

In the last trial, 9 farm samples, 0-6" and 6-12" depths were obtained from the Saskatchewan Soil Testing Laboratory. A subsample was ground to pass through a 60 mesh sieve to eliminate the sampling error. On the same day, triplicate samples of each soil were extracted by both methods to eliminate the possibility of inorganic phosphate difference due to storage effect.

The results in Table 3 show that the mean of the activated carbon treated sodium bicarbonate extracts contained approximately 1 μg P g^{-1} more inorganic phosphate than did the extracts treated with polyacrylamide. Comparison of the results obtained from the <60 mesh soils with the <10 mesh soils showed that grinding the soils to a finer mesh size (Table 3) also increased the amount of inorganic phosphate in the carbon treated sodium bicarbonate extracts. As no significant difference was found between the polyacrylamide treated extracts and carbon treated extracts of the same mesh size soil (Table 1) the difference now observed between the two extracts may be attributed to grinding effects.

The amount of inorganic phosphate in the polyacrylamide treated extracts were significantly related (Fig. 1) to phosphate in the carbon treated extract ($r = .986$, $P \gg 0.001$). In most cases the soil test values obtained with polyacrylamide would be very slightly lower than those obtained with activated carbon. It is difficult to advance reasons why there should be a slight difference (approximately 1.2 μg g^{-1} soil) in values obtained. It may be partly due to the abrasive effect of the soil and solution shaking on the activated carbon. However from a practical point of view these differences are not of great significance.

These results are in agreement with those found by Banderis et al. (1975) who found that for all soil types, the results expressed as (polyacrylamide value)/(carbon value) X 100 varied from 95.1 to 104.8 with a mean of 99.0. Subsequent to their work the polyacrylamide method, which greatly reduces technical problems in the laboratory, has been adopted by the British Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food as a standard method for the determination of available phosphate in soils.

Conclusion

The use of polyacrylamide has been tested on representative Saskatchewan soils and a comparison made with the activated carbon method presently in use. It was concluded that the polyacrylamide method could be substituted for the activated carbon method without significantly altering the amount of inorganic phosphate extracted and also eliminating the laboratory problem of both finding phosphate free carbon and the messy process of washing and drying contaminated carbon.

Table 3. Comparison of inorganic phosphate extracted by sodium bicarbonate containing either polyacrylamide or activated carbon.

Depth (in.)	Soil Association and Texture	<60 mesh soil		Routine soil testing analysis on <10 mesh soil carbon
		Polyacrylamide	Carbon	
		P $\mu g\ g^{-1}$		P $\mu g\ g^{-1}$
0-6	Thick Black, Canora, sandy loam	5.49 ± 0.08	7.80 ± 0.40	7.5
0-6	Thick Black, Canora, sandy loam	5.00 ± 0.35	7.20 ± 0.40	6.0
6-12	Grey, Waitville, sandy loam	2.00 ± 0.0	2.80 ± 0.0	2.0
6-12	Dark Brown, Elstow, silt loam	2.60 ± 0.20	3.47 ± 0.12	3.5
0-6	Dark Brown, Elstow, silt loam	13.07 ± 0.83	13.20 ± 0.20	10.0
6-12	Dark Brown, Weyburn, clay loam	3.93 ± 0.42	4.47 ± 0.23	4.5
0-6	Dark Brown, Weyburn, loamy sand	13.07 ± 0.70	14.13 ± 0.12	9.2
0-6	Thick Black, Canora, loam	3.60 ± 0.69	4.47 ± 0.12	4.5
0-6	Brown, Septre, heavy clay	4.00 ± 0.28	4.80 ± 0.40	5.0
Mean value		5.86	6.93	5.8

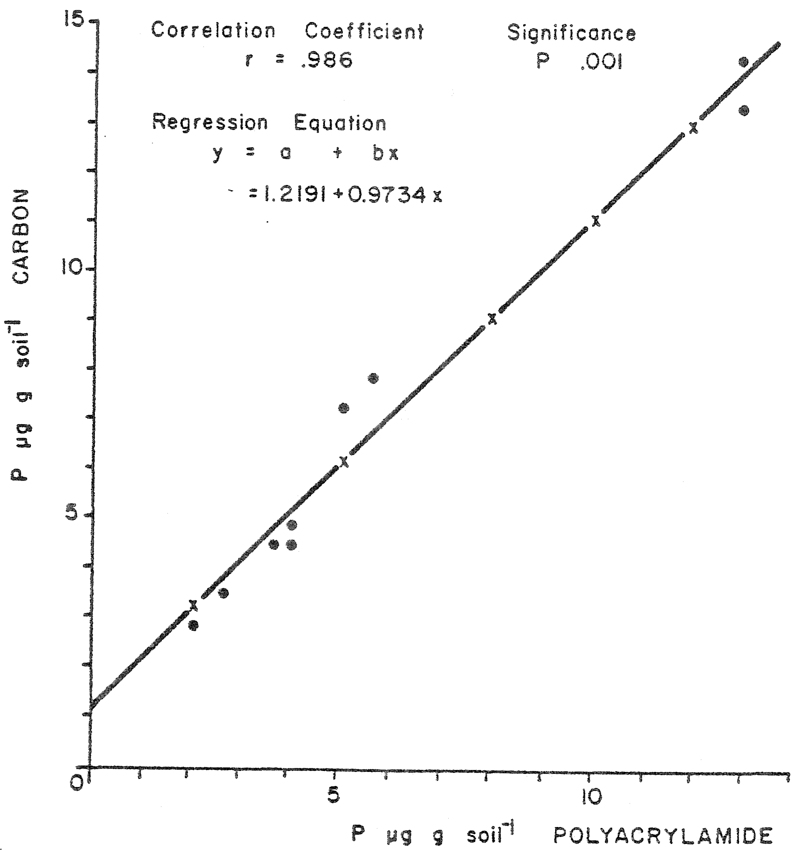

Fig. 1. Comparison of the amounts of inorganic phosphate extracted from soils with $NaHCO_3$ containing either activated carbon on polyacrylamide.

References

Banderis, A.S., D.H. Barter and K. Henderson. 1976. The use of polyacrylamide to replace carbon in the determination of "Olsen's" extractable phosphate in soil. J. Soil Sci. 27: 71-74.

Bowman, R.A., S.R. Olsen and F.S. Watanabe. 1978. Greenhouse evaluation of residual phosphate by four phosphate methods in neutral and calcareous soils. Soil Sci. Soc. Amer. J. 42: 451-454.

Hamm, J.W., F.G. Radford and E.H. Halstead. 1970. The simultaneous determination of nitrogen, phosphorus and potassium in sodium bicarbonate extracts of soils. Advances in Automated Analysis 2: 65-69.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Circ. 939.

Watanabe, F.S. and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci. Soc. Amer. Proc. 29: 677-678.