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Effect of Cow Dung, Biogas Slurry and Vermicompost on Phosphorus Adsorption Behavior of Soil

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Abstract

One of the approaches for phosphorus fertilizer management is controlling the soil phosphorus adsorption behavior. To examine the effect on phosphorus adsorption behavior, three amended soil samples were prepared by mixing 10% (w/w in dry basis) cow dung, biogas slurry and vermicompost with soil. Phosphorus adsorption behavior was examined by using Langmuir, and Temkin adsorption isotherms. Initially, biogas slurry and vermicompost increased the maximum phosphorus adsorption capacity (MPAC) of soil from 461 µg g^{-1} (control) to 558.0357 and 586.17 µg g^{-1} respectively, and then decreased steadily and reached 429.92 and 398.41 µg g^{-1} respectively in five weeks. Whereas in case of cow dung, MPAC was initially decreased, then reached maximum in 17 days and ultimately decreased. Thus application of cow dung along with phosphate fertilizer seems to increase the loss of the fertilizer through runoff and leaching. Conversely, biogas slurry and vermicompost prevent phosphorus loss by regulating phosphorus release through initial enhancement followed by gradual decrease in phosphorus adsorption capacity of soil. Both biogas slurry and vermicompost can be considered as good soil amendments as they have the ability to control the release of phosphorus fertilizer as per the need of the plants.

Keywords: Adsorption isotherm; Vermicompost; Biogas slurry; Cow dung; Phosphorus adsorption capacity.

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1. Introduction

Common agricultural practices such as excessive use of agrochemicals degrade soils, pollute water resources and contaminate the atmosphere. There is increasing concern about interrelated environmental problems such as soil degradation, desertification,

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erosion, and accelerated greenhouse effects and climate change. In response to environmental concerns, soil fertility and chemical cost, organic agriculture has become an increasingly popular option [1–3].

Cow dung, biogas slurry and vermicompost are three important organic fertilizers. Biogas slurry obtained from the biogas plant may be considered as a good source of organic fertilizer as it contains considerable amounts of both macro and micronutrients [4]. Organic matter (OM) that has been digested by worms is called vermicompost. Vermicomposting reduces volume and adds additional microbial diversity to the compost [5]. These organic fertilizers can also be used for proper management of phosphorus fertilizer by amending soil phosphorous adsorption capacity.

Phosphorous adsorption capacity of soil reveals the portion of applied phosphorus adsorbed to soil. Higher phosphorus adsorption capacity means phosphorus is strongly retain to soil, not available for plant uptake. Whereas lower value of adsorption capacity means higher phosphorus availability for plant uptake but there is strong chance of runoff by water, causes environmental pollution and economical loss [6-9].

Optimum phosphorus adsorption capacity of soil is required for efficient use of phosphorus fertilizer. MPAC may be corrected by amending soil with organic fertilizers that contain mainly organic matter [10]. The objective of this study is to investigate the short term effect of cow dung, biogas slurry and vermicompost on phosphorus adsorption characteristics of soil to get insight on the importance of these organic fertilizers for supporting phosphorus fertilizer management.

2. Experimental

2.1. *Materials*

NaOH, HCl, H_2SO_4, $SnCl_2$, ammonium molybdate, phenolphthalein indicator, glycerol and Na_2HPO_4 used in analysis were of analytical grade. Soil sample was collected from non-cultivated area of Rajshahi University Campus, Bangladesh. The samples taken from the upper 15 cm soil layer were air-dried, ground and sieved through 2 mm sieve to increase the uniformity of the experiment and preserved in a polyethylene plastic packet. The particle size distributions of the soil samples were 38.21% silt, 54.68% sand and 7.11% clay with texture grade of sandy loam. OM content and pH of the soil were 0.83% and 6.63 respectively.

2.2. *Sample treatments*

Three organic fertilizers, cow dung, biogas slurry and vermicompost were collected in different polyethylene plastic packets from a home based farm situated in Chapai Nawabganj district in Bangladesh. Then cow dung, biogas slurry and vermicompost were mixed with soil in 10% (w/w) dry basis respectively and were watered sufficiently to ensure maximum miscibility. The final samples were kept at ambient temperature till analysis.

Four soil samples named as cow dung amended soil (CD), biogas slurry amended soil (BGS), vermicompost amended soil (VC) and control soil were characterized by analyzing their pH, conductivity and organic carbon content. Soil pH and conductivity were measured in 1:5 soil/water suspension using pH and conductivity meters [11]. Total organic carbon (TOC) was determined by semi-quantitative method [12]. Phosphorus adsorption capacity was determined by the reported method [13]. A range of phosphorus solutions (0, 10, 20, 30, 40, 50, 60 and 70 mg L^{-1}) was prepared by dissolving potassium dihydrogen phosphate (KH_2PO_4) in 0.01 M aqueous calcium chloride ($CaCl_2.2H_2O$) solution. Then 0, 100, 200, 300, 400, 500, 600 and 700 μg phosphorus per gram of soil were prepared by mixing 5 g soil samples with 50 mL of these phosphorus solutions in 100 mL reagent bottles. The samples were then shaken for 24 h at room temperature (25°C) followed by centrifugation at 12,000 rpm for 12 min and finally filtered. The filtrates were analyzed for remaining phosphorus in solution following the reported method [14] using UV-visible spectrophotometer (UV-1800, SHIMADZU). The amount of phosphorus adsorbed per gram of soil was calculated from the difference in the phosphorus added to the soils and the phosphorus present in the solution.

2.3. *Adsorption isotherm*

Adsorption isotherms describe solute adsorption by solids from an aqueous solution at constant temperature and pressure and show the amount of solute adsorbed as a function of equilibrium concentration in solution. The phosphorus adsorption data for the soils used in this study were fitted into the following adsorption equations.

2.3.1. *Langmuir adsorption isotherm*

$$\frac{c}{(x/m)} = \frac{1}{k_L b_L} + \frac{c}{b_L} \qquad \text{or,} \quad \frac{c}{q} = \frac{1}{k_L b_L} + \frac{c}{b_L}$$

Here c is equilibrium concentration of phosphorus in solution (μg mL^{-1}), q (x/m) is the mass of phosphorus adsorbed per unit mass of soil (μg g^{-1}), k_L is a constant related to bonding energy of phosphorus to the soil, and b_L is the MPAC (μg g^{-1}soil).

2.3.2. *Temkin adsorption isotherm*

$$\frac{x}{m} = a_T + b_T \ln c \qquad \text{or,} \quad q = a_T + b_T \ln c$$

Here a_T and b_T are constants. The b_T value of Temkin equation is considered as the phosphorous buffering capacity of soil (μg g^{-1}) [13].

3. Results and Discussions

Study on the potency of cow dung, biogas slurry, and vermicompost was carried out by measuring some physico-chemical properties like pH, conductivity, organic carbon content and phosphorus adsorption characteristics of the amended soil samples. To be useful as proper organic amendment, an organic fertilizer should have the ability to correct the soil pH, increase nutrient availability and control the release of phosphorus fertilizer as per the need of the plants.

3.1. *Effect on pH*

The pH level of the soil directly affects the availability of essential soil nutrients for plant growth. The soil pH was found to change upon the application of the organic fertilizers. The higher pH values of organic fertilizer amended soils compared to the control one reflect the ability of the organic fertilizers to correct the pH of acidic soil. The pH values for CD and BGS were higher than 7.0 and the change in pH values with time were irregular (Table 1). However, the pH value for BGS amended soil is not so high and it is closer to neutral pH value. On the other hand, the pH value of VC was almost constant at 7.0 over five weeks which reflects its soil buffering capacity. Buffering of soil is necessary for normal plant growth. The optimum uptake of most nutrients occurs at a soil pH near neutral. The availability of most macronutrients (nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium) decreases as soil acidity increases [15]. Therefore, application of vermicompost and BGS to moderately acid soils tends to increase the availability of these nutrients.

Table 1. Effect of organic fertilizers on pH, conductivity and organic carbon content of soil.

Soil samples	pH			Conductivity/S			Organic Carbon Content (%)
	0^{th} day	17^{th} day	35^{th} day	0^{th} day	17^{th} day	35^{th} day	
Control	6.62	7.01	6.80	1.99×10^{-3}	2.01×10^{-3}	2.01×10^{-3}	0.83
CD	7.14	7.61	7.42	2.07×10^{-3}	2.38×10^{-3}	1.90×10^{-3}	7.41
BGS	7.10	7.32	7.21	2.07×10^{-3}	2.30×10^{-3}	2.31×10^{-3}	4.81
VC	7.01	7.02	7.00	2.15×10^{-3}	2.56×10^{-3}	2.60×10^{-3}	4.54

3.2. *Effect on conductivity*

Organic fertilizer amended soils showed increased conductivity compared to control soil (Table 1). Conductivity of CD increased first, reached maximum on 17 days and then decreased. Conductivity of BGS and VC increased continually with time. However, the increase rate of VC was higher than that of BGS. Conductivity of solution indicates the presence of water soluble metal ions, including plant nutrients. Increasing conductivity with time is an evidence for nutrient mineralization.

3.3. *Effect on organic carbon content*

The control soil had very low organic carbon content (0.83%). Percentage of TOC increased significantly in CD, BGS and VC in a range between 4.54-7.41%. CD had the highest TOC. TOC decreased in biogas slurry due to conversion of some organic matter to low molecular gases which is used as fuel. TOC was decreased more in vermicompost. Aira *et al.* reported that earthworms modified substrate conditions subsequently enhanced carbon losses from the substrates through microbial respiration in the form of CO_2 [16].

3.4. *Effect of organic fertilizers on soil phosphorus adsorption characteristics: Phosphorus Adsorption isotherm*

The amounts of adsorbed phosphorus against equilibrium concentration were fitted to the linear form of Langmuir and Temkin adsorption isotherms by least square analysis method. The fitting parameters and coefficients of correlation are listed in Table 2.

Table 2. The fitting parameters of Langmuir and Temkin adsorption isotherms.

Time	Soil sample	Langmuir isotherm			Temkin isotherm		
		k_L	b_L	R^2	a_T	b_T	R^2
0^{th} day	Control	0.076	461.894	0.991	-28.742	101.984	0.989
	CD	0.060	393.236	0.995	-46.905	87.249	0.992
	BGS	0.075	558.036	0.995	-31.004	121.016	0.992
	VC	0.075	586.166	0.992	-26.263	124.351	0.983
17^{th} day	Control	0.069	464.468	0.990	-44.731	98.655	0.994
	CD	0.124	531.067	0.997	25.024	116.557	0.990
	BGS	0.074	507.614	0.982	-34.528	100.138	0.984
	VC	0.087	514.933	0.998	-14.585	112.708	0.990
35^{th} day	Control	0.067	457.247	0.995	-38.327	99.511	0.990
	CD	0.066	433.651	0.996	-41.842	96.095	0.993
	BGS	0.062	429.923	0.989	-52.106	97.374	0.989
	VC	0.061	398.406	0.994	-50.608	90.184	0.993

It is discernible that the values of correlation coefficients are ≥0.98 indicating that adsorbed phosphorus versus equilibrium concentration data support both adsorption models for studied organic fertilizers amended soils and allow us to compute some important characteristic parameters of soil. The energy of adsorption (EA) and MPAC, respectively were calculated from slope, k_L and intercept, b_L of Langmuir isotherm (Fig. 1) whereas, buffer capacity from the slope, b_T of Temkin isotherm (Fig. 2). It is apparent from Table 2 that fitting parameters for control soil were approximately unchanged for 35 days. On the other hands, the values of the fitting parameters for CD, BGS and VC samples changed with time. These results indicate that the organic fertilizers, cow dung, biogas slurry and vermicompost can change and regulate the adsorption characteristics of soil.

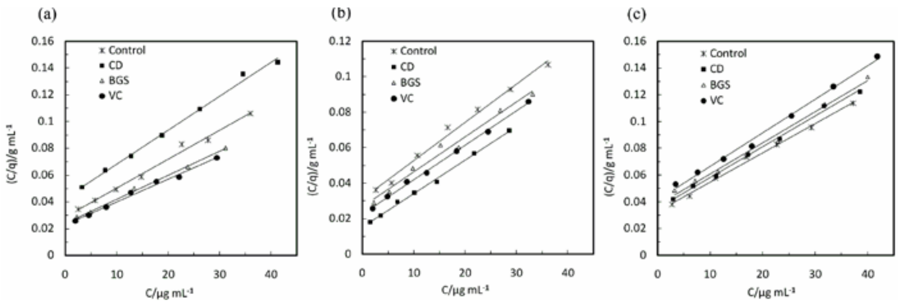

Fig. 1. Langmuir phosphate adsorption isotherm for Control and CD, BGS and VC samples for (a) 0^{th} day, (b) 17^{th} day and (c) 35^{th} day. c is the equilibrium phosphorus concentration in solution and q is the mass of phosphorus adsorbed per unit mass of soil.

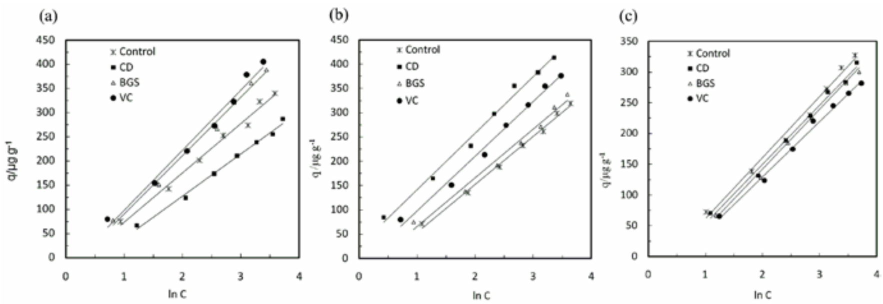

Fig. 2. Temkin phosphate adsorption isotherm for Control and CD, BGS and VC samples for (a) 0^{th} day, (b) 17^{th} day and (c) 35^{th} day. c is the equilibrium phosphorus concentration in solution and q is the mass of phosphorous adsorbed per unit mass of soil.

3.5. *Comparison of phosphorus adsorption capacity with time*

A comparison of MPAC (b_L) of control, CD, BGS and VC is shown in Fig. 3. Initially cow dung amended soil had lower b_L value than others. It showed an irregular change in b_L and ultimately reached the b_L value of BGS in 35 days. The irregular change in b_L value of CD was attributed by changing physicochemical characteristics of the substrates. Fresh cow dung contains unstable OMs [17] which are very poor substrate for adsorption; even it inhibits adsorption by blocking adsorption sites [18]. However, these unstable OMs were converted to stable substrate [19] following PO_4^{3-} adsorption with time.

On the other hand, initially BGS and VC showed higher b_L values than control soil sample and then decreased gradually and reached the values lower than control one. Biogas slurry and vermicompost mainly supply OM/humus substances to soil. Soil contains mineral such as oxide of Fe and Al. Gerke proposed that, the Fe from oxide in soil is complexed by humus substances [20]. BGS and VC contain humus which is stable OM substrate. These complexes provided more sorption sites for PO_4^{3-} via the formation of PO_4-Fe-OM ternary complexes, resulting in the increased PO_4^{3-}

adsorption capacity. Fiona *et al.* noticed the change of PO_4^{3-} sorption capacities of soil (OM/ferrihydrite) systems as they were aged [21]. They also found that regardless of the amount of OM, all systems showed decreasing PO_4^{3-} sorption capacities during aging. It has been hypothesized that OM can complex with Fe from oxide minerals in soil, which provide more sorption sites for PO_4^{3-} via the formation of Fe-PO_4-OM ternary complexes. Furthermore, since it is well-established that competition for adsorption sites occurs between inorganic, specifically adsorbed anions, competition between organic matter and phosphate leading to decreased phosphate adsorption could be anticipated; however, this is still disputed. Whereas Appelt *et al.* found no change in PO_4^{3-} adsorbed by one soil after addition of dissolved OM [22]. Sibanda and Young found that organic matter in solution strongly decreased PO_4^{3-} adsorption onto Al and Fe oxides thus onto soils [23]. The b_T value of Temkin equation is considered as the phosphorous buffering capacity (retention capacity of adsorbed phosphorous) of soil. Table 2 shows that b_T is strongly correlated with MPAC. Greater MPAC means greater phosphorous buffering capacity. Phosphorous buffering capacity followed the same trend as MPAC.

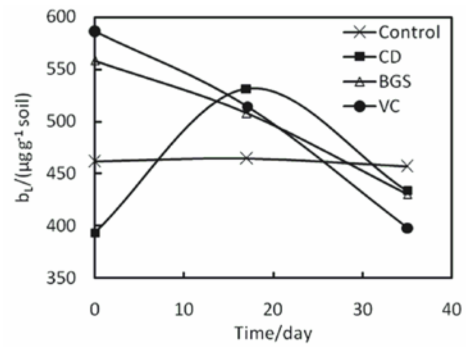

Fig. 3. Change in MPAC (b_L) of soil samples (control, CD, BGS and VC) with time.

3.6. *Potency of cow-derived fertilizers to support phosphorus fertilizer management*

Study result showed that, initially biogas slurry and vermicompost increase MPAC of phosphorous from 461.893 µg g^{-1} (for control soil) to 558.035 µg g^{-1} soil and 586.166 µg g^{-1} soil respectively. On 17th day MPAC of BGS and VC decreased to 531.06 µg g^{-1} soil and 507.61 µg g^{-1} soil respectively. MPAC of BGS and VC get lower in further two weeks to 433.651 and 429.922 µg g^{-1} soil. Increase in MPAC means the increase in the phosphorus retention capacity of the soil and thus decrease in the runoff of phosphorus fertilizer to the surface water bodies. If phosphorus fertilizer is applied to the amended soil, initial loss of phosphorus fertilizer from land will be prevented which in turn will be helpful to reduce the production cost for crops and also reduce eutrophication risk in the surface water bodies. Moreover, as the time elapsed the phosphorus fertilizer is utilized by the plant and the amount of phosphorus fertilizer in the soil gets reduced. So the soil amendments should have the capacity to reduce MPAC of soil with time and release phosphorus fertilizer as per the demand of plants. From the above mentioned data it is obvious that both biogas slurry and vermicompost have the ability to control the release of phosphorus fertilizer. Therefore, they could be considered as good soil amendments for agro-environmental benefits. On the other hand, cow dung caused an initial decrease in MPAC of phosphorous to 393.236 µg g^{-1} soil. However, on 17th day of amendment MPAC was increased to 531.06 µg g^{-1} soil and ultimately decreased to 433.651 µg g^{-1} soil after 5 weeks. To get the agro-environmental benefits from cow dung phosphorus fertilizer should be used at least two weeks after its application to the soil.

4. Conclusion

Study on the potency of three cow-derived fertilizers, cow dung, biogas slurry and vermicompost as soil amendments was carried out by measuring some physico-chemical properties of soil like pH, conductivity, organic carbon content and phosphorus adsorption characteristics. The pH values of BGS and VC were within the range where the nutrient availability of the plants is the maximum. Conductivity of the amended soil samples was increased with time whereas that for the control one was remained almost constant. As expected, organic carbon of the amended soil samples was also found to be higher than the control. For BGS and VC, initially the MPAC increased and then decreased with time. On the other hand for CD, initially the MPAC was decreased and then increased with time, reached a maximum and ultimately decreased. Care should be taken when phosphorus fertilizer is used along with cow dung as there is a chance for a significant loss of phosphorus fertilizer through runoff that may cause the eutrophication. Both biogas slurry and vermicompost can be considered as good soil amendments as they have the ability to correct the soil pH, increase nutrient availability and control the release of phosphorus fertilizer as per the need of the plants. Control release of phosphorus fertilizer is also necessary to prevent eutrophication. Therefore, biogas slurry and vermicompost should be used for agro-environmental benefits. However, biogas slurry seems to be more cost effective than vermicompost as the former is less expensive.

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References

1. Q. Schiermeier, Nature, **502(7473)**, 607 (2013). http://dx.doi.org/10.1038/502607a
2. C. Macilwain, Nature, **428**, 792 (2004). http://dx.doi.org/10.1038/428792a

3. S. B. Kramer, J. P. Reganold, J. D. Glover, B. J. M. Bohannan, and H. A. Mooney, Proc. Natl. Acad. Sci. U. S. A. **103(12)**, 4522 (2006). http://dx.doi.org/10.1073/pnas.0600359103
4. M. S. Islam, in Bangladesh Bio-slurry Use in Agriculture - *Proc. International Workshop on the Use of Bioslurry Domestic Biogas Programmes* (Bangkok, Thailand, 2006) pp. 14-15.
5. A. Yadav, R. Gupta, and V. Garg, Int. J. Recycl. Org. Waste Agric. **2**, 21 (2013). http://dx.doi.org/10.1186/2251-7715-2-21
6. M. Islas, L. Solı´s, and M. V. Esteller, Env. Earth Sci. **73(3)**, 1441 (2014).
7. S. M. Mehdi, O. Rehman, A. M. Ranjha, and M. Sarfraz, World Appl. Sci. J. **2**(4), 244 (2007).
8. J. Qiu, Nature (2010). http://dx.doi.org/10.1038/news.2010.498
9. M. Del Bubba, C. A. Arias, and H. Brix, Water Res. **37(14)**, 3390 (2003). http://dx.doi.org/10.1016/S0043-1354(03)00231-8
10. D. Xu, J. Xu, J. Wu, and A. Muhammad, Chemosphere **63(2)**, 344 (2006). http://dx.doi.org/10.1016/j.chemosphere.2005.08.036
11. G. E. Rayment and F. R. Higginson, Australian Laboratory Handbook of Soil and Water Chemical Methods (Inkata Press, Melbourne, 1992).
12. B. A. Schumacher, Methods For The Determination of Total Organic Carbon (TOC) in Soils and Sediments, US Environmental Protection Agency, Ecological Risk Assessment Support Centre, National Exposure Research Laboratory (Las Vegas, 2002).
13. M. F. Ahmed, I. R. Kennedy, A. T. M. A. Choudhury, M. L. Kecske´s, and R. Deaker, Commun. Soil Sci. Plant Anal. **39**, 1269 (2008). http://dx.doi.org/10.1080/00103620802003963
14. J. G. Ibanez, M. Hemandez-Esparza, C. Doria-Serrano, A. Fregoso-Infante, and M. M. Singh, Environmental Chemistry: Microscale Laboratory Experiments (Springer, New York, 2008). http://dx.doi.org/10.1007/978-0-387-49493-7
15. M. Silveira, The Florida Cattleman Livestock J. **3,** 1 (2013).
16. M. Aira and F. D. J. Monroy, Sci. Total Environ. **385**, 252 (2007). http://dx.doi.org/10.1016/j.scitotenv.2007.06.031
17. R. Kumar and N. Yadav, J. Chem. Eng. Process Technol. **5(02)**, 186 (2014).
18. A. D. Site, J. Phys. Chem. Ref. Data **30(1)**, 253 (2001).
19. P. Vijayaraghavan, A. Vijayan, A. Arun, J. K. Jenisha, and S. G. P. Vincent, Saudi J. Biol. Sci. **21(1)**, 27 (2014). http://dx.doi.org/10.1016/j.sjbs.2013.04.010
20. J. Gerke, Geoderma **59**, 279 (1993). http://dx.doi.org/10.1016/0016-7061(93)90074-U
21. R. K. Fiona, H. Dean, and M. James, in Phosphate Sorption to Organic Matter/ferrihydrite Systems as Affected by Aging Time - *Proc.-19th World Congress of Soil Science, Soil Solution for a Changing World* (Brisbane, Australia, 2010) pp. 84–87.
22. I. De Vicente, H. S. Jensen, and F. Andersen. Sci. Total Environ. **389(1)**, 29 (2008). http://dx.doi.org/10.1016/j.scitotenv.2007.08.040
23. H. Sibanda and S. Young, J. Soil Sci. **37**, 197 (1986). http://dx.doi.org/10.1111/j.1365-2389.1986.tb00020.x